THE
ENGINEERING REVIEW.

Edited by

C. EDGAR ALLEN.

Vol. XVIII. JANUARY, 1908. No. 1.

Live Steam Feed Heating.*

By A. H. GIBSON, M.Sc., A.M.Inst.C.E.

It is now some years since Mr. John Kirkaldy first proposed heating the cold feed water for a marine boiler by means of live steam taken either from the main or from an auxiliary boiler, before pumping it into the boiler.

This was first proposed as a means of alleviating the stresses produced by the unequal expansion and contraction in the boiler shell, and the proposer of the scheme was probably as sceptical as anyone else when it was reported that not only was the desired end gained, but the coal consumption of the plant was at the same time considerably reduced, while its evaporative capacity was increased. This scepticism was apparently justified both from a theoretical thermodynamical standpoint and from that of the "man in the street." From the first of these points of view the additional economy was manifestly impossible. Here we have cold water suddenly heated by intimate contact with live steam at boiler temperature—a process which is thermodynamically as irreversible, and therefore as wasteful as that of heating by direct pumping of cold water into the boiler—while in addition we have losses due to radiation, and probably also to leakage, which are inseparable from the process.

From the common sense point of view it seemed at first sight just as absurd that the mere process of first producing steam and then condensing it to heat the feed water for the same boiler, should lead to any economy over the direct process of heating the feed water in the boiler itself.

However, in spite of the apparent paradox, the fact that a saving is actually obtained by the process has been conclusively proved by so many observers under different conditions of working, that there is no ground for the scepticism which it must be confessed still exists among the older type of engineer. While the value of the system has become almost universally recognised, the reason for its success

* Prize Article.

is far from generally understood. Obviously it cannot be explained by any process of reasoning from a thermodynamical basis, and it remains to inquire into the physical causes which may effect an economy sufficiently great to more than counterbalance the thermodynamic loss.

Now although the whole science of steam raising is still in a somewhat nebulous state, one or two facts have been fairly well demonstrated by experiment, and these at all events provide a clue to the economy of the live steam feed heater.

In the first place it is well known that the transference of heat from a hot boiler plate to water, by conduction alone, is an extremely slow process, and that the rate of transference—other things being equal—increases with the velocity of flow of the water over the hot-plate, and therefore with the rapidity of circulation in the boiler. It is also well known that the flow of heat through a boiler-plate depends directly on the difference of temperature between its extreme surface layers, and, neglecting for the time being the debatable point as to whether the transference of heat from the hot gases on one side of the plate to the water on the other varies directly as the difference or as the square of the difference of their temperatures, and simply recognising that it increases with this difference, we see that in a given boiler, having a given furnace temperature and passing a given weight of flue gases per hour, this transference will be greater as the temperature of the water surface of the plate diminishes. Any cause tending to lower this latter temperature will, by causing an increased flow of heat through the plate and a consequent reduced rejection of heat in the flue gases, increase the efficiency of the heating surface and generally the efficiency of working.

And here we should appear at first sight to be as far from an explanation as ever, since the introduction of hot, instead of cold, feed into a boiler will naturally raise the mean boiler temperature, and might be expected to raise the temperature of the hot-plates. Actually, however, this is not the case—and for two reasons which will now be considered somewhat in detail.

In the first place, the introduction of cold feed water into a boiler almost inevitably retards the circulation. The magnitude of this effect of course varies with the position of the feed inlet, and will be greatest when the down-coming stream of cold water directly meets an uprising stream of hot water and steam bubbles. On the other hand, hot feed —feed at boiler temperature—will readily enter into the natural circulation of the boiler, so that, in the latter case, it may be expected that the circulation will be better and more regular, and the velocity of flow of the water over the heating surfaces more rapid. This conclusion is abundantly justified by the result of experiment.

Now experiments conclusively show that the temperature of the film of water immediately in contact with a furnace plate may be very considerably higher than the mean temperature of the water in the boiler so long as ebullition is not taking place, this temperature difference being reduced as the film is more or less rapidly displaced by an increased velocity of flow over the hot surface. This being so, it follows that, within limits, the more rapid the circulation the lower the temperature of the water surface of the plate; the steeper the temperature gradient between its two faces; and the greater the transference of heat from the hot gases.

But important as this undoubtedly is during the preliminary stages of heating, it does not attain its maximum effect until ebullition is actually set up. When this takes place, the rate of absorption of latent heat by the steam at its instant of formation at the surface of the plate is so rapid, that the temperature of this surface does not rise appreciably above that corresponding to the pressure of the steam. The comparatively great increase in the temperature gradient which may then take place, and the resultant increase

in the rate of transmission of heat through the plate, were strikingly shown in a series of experiments carried out by the late Sir Wm. Anderson. Using a steam jacketed pan containing water, in one experiment 260 B.T.U. per square foot of heating surface per hour per degree difference in temperature between water and steam, were transmitted through the plate when heating the water. Immediately the water began to boil, this value increased to 606 B.T.U.

In a second experiment the amount rose from 368 B.T.U. to 660 B.T.U., an increase of 80 per cent.

Although these are probably extreme cases, yet they indicate very clearly the probable reason for economy, for while in the boiler fed with cold water the heating surface has to perform two duties—that of heating up the feed water to boiler temperature and that of evaporating this water, the first of these being a comparatively inefficient process, —with hot feed water the sole duty of the heating surface consists in producing evaporation, so that, with the same steam pressure, a lower temperature is not to be expected at the plate surface. This would appear to be borne out by the few experiments which are available.

The conclusion as to evaporation being a more efficient process than water heating, is indirectly borne out by the behaviour of a boiler when standing under banked fires and with stop valve closed. A slight easing of the safety valves, by slightly reducing the pressure and allowing the formation of steam, reduces the temperature of the flue gases at exit. Further evidence of this is provided by the results of some boiler efficiency tests published by Messrs. E. Green & Sons, Ltd. Here the increased efficiency actually obtained by the use of hot feed supplied by an economiser was found to be in excess of that to be theoretically expected from a calculation of the heat absorbed from the flue gases, by an amount varying from 3·7 to 5·4 per cent. of the total efficiency, or from 15 to 23 per cent. of the increased efficiency.

Evidence of the cooling effect of rapid evaporation on the water side of the plate is afforded by the results of experiments by Miss E. M. Bryant (Proc. Inst. C.E., Vol. 132, p. 274), on the transmission of heat through a furnace plate. In the course of these experiments "a curious effect was noticed. On several occasions when the vessel boiled dry, a sudden fall of the temperature of the plate, especially over its outer surface, occurred, followed by a rapid rise. The cooling is evidently due to rapid evaporation taking place when the water is nearly boiled away, and is followed by a rise in temperature as soon as the surface is dry."

As has been pointed out, viewed from a thermodynamic standpoint, the system of feed heating by live boiler steam is bad. The system may, however, be considerably improved if the feed, instead of being heated directly by steam at boiler pressure, be heated in stages by steam which has already expended part of its energy in doing useful work.

For example, in the case of a plant including a triple expansion engine, the feed would be heated by the exhaust steam up to the exhaust temperature, and would then be heated in turn by steam from the low pressure receiver, the intermediate receiver, and the high pressure receiver, finally entering the boiler at a temperature very slightly less than that corresponding to the steam pressure. The process is now much more nearly reversible and the possibilities of efficiency are at once increased.

A consideration of the temperature-entropy diagram for an ideal plant working under each of these conditions will make this more clear. In Fig. 1, assuming our ideal plant to follow the "Rankine" cycle, its efficiency with feed water at a temperature T_2, would be given by the ratio of the areas *B C D A* and *B C D E F A*. On the other hand, with feed water heated to a temperature T_1, by the direct action of steam at T_1, if the area *G K E C* represent the energy received by the feed water in this way, the efficiency of the cycle is given by the ratio of the areas *B G H A* and *B G H K F A*, a ratio

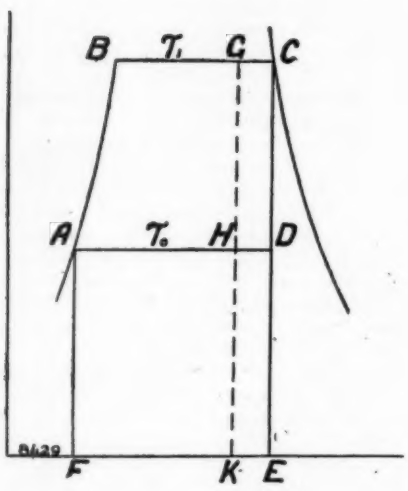


FIG. 1.

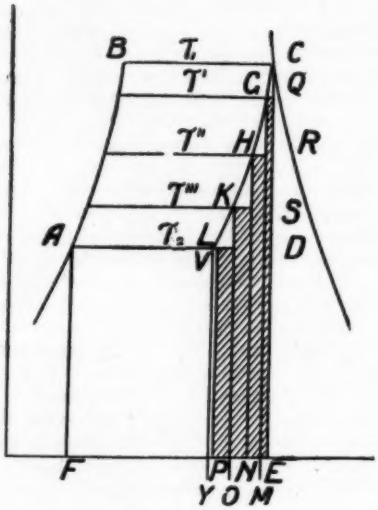


FIG. 2.

which is evidently less than that of *B C D A* to *B C D E F A*.

If, however, as indicated in Fig. 2, heating take place in four stages, and at temperatures T_1, T'', T''', and T_2, the energy given to the feed water by the steam from the high pressure receiver will be represented by the area *G E;* from the intermediate receiver, by the area *H M;* from the low pressure receiver by the area *K N;* and from the exhaust steam by the area *L O*. The efficiency is now measured by the ratio of the areas *B C Q G R H S K D L A* and *B C Q G R H S K D L P F A*.

In the limit, with an infinite number of stages, and an infinitely small difference of temperature at each stage, the energy given to the feed water would be represented by the area under the smooth curve *C G H K V*, and the plant, now working under the "Carnot" cycle, would, in theory, be as efficient as any plant working between the given limits of temperature could possibly be. The efficiency is now represented by the ratio of the areas *B C G H K V R* and *B C G H K V Y F A*.

While the ideal states of affairs here outlined are of course unattainable in practice, yet the gain in the case of an actual plant will be proportionately as great as in the ideal plant.

In the live steam feed heater of Messrs. G. and P. Weir, as applied to a compound engine with heating in a single stage, water is pumped through a spring-loaded valve into the heater, which is supplied with live steam from the low-pressure receiver. The water falls as spray to the bottom of the heater from which it is pumped directly into the boiler. Where applied to multiple expansion engines, it is however more usual to pump the feed water through heating coils placed in each receiver in turn. This method is found to give satisfactory results, although great care must now be taken to provide an effective drainage system for the steam condensed in these receivers.

So closely allied to the subject of live steam feed heating as to be almost identical with it, is that of thermal storage for a steam boiler.

The thermal storage system simply consists in the addition to a boiler, or battery of boilers, of a large storage

tank of considerable capacity, suitable connections being made to enable cold feed water to be pumped into this tank, to enable steam at boiler pressure to be constantly in communication with the surface of this water, and to enable the feed water heated by this steam to enter the boilers as required.

Fig. 3 indicates the method of application to a single Babcock and Wilcox boiler. Here *A* is the storage tank, mounted over the steam drum *B* of the boiler. The pipe *C* admits steam to the upper surface of the water in *A*, while the pipe *D* allows of the heated feed water being drawn off into the boiler. *E* is the delivery pipe from the feed pumps.

While this arrangement, looked upon simply as a feed heater using live steam at boiler pressure, cannot be expected to give such good results as the multiple stage heaters, to which reference has previously been made, yet repeated

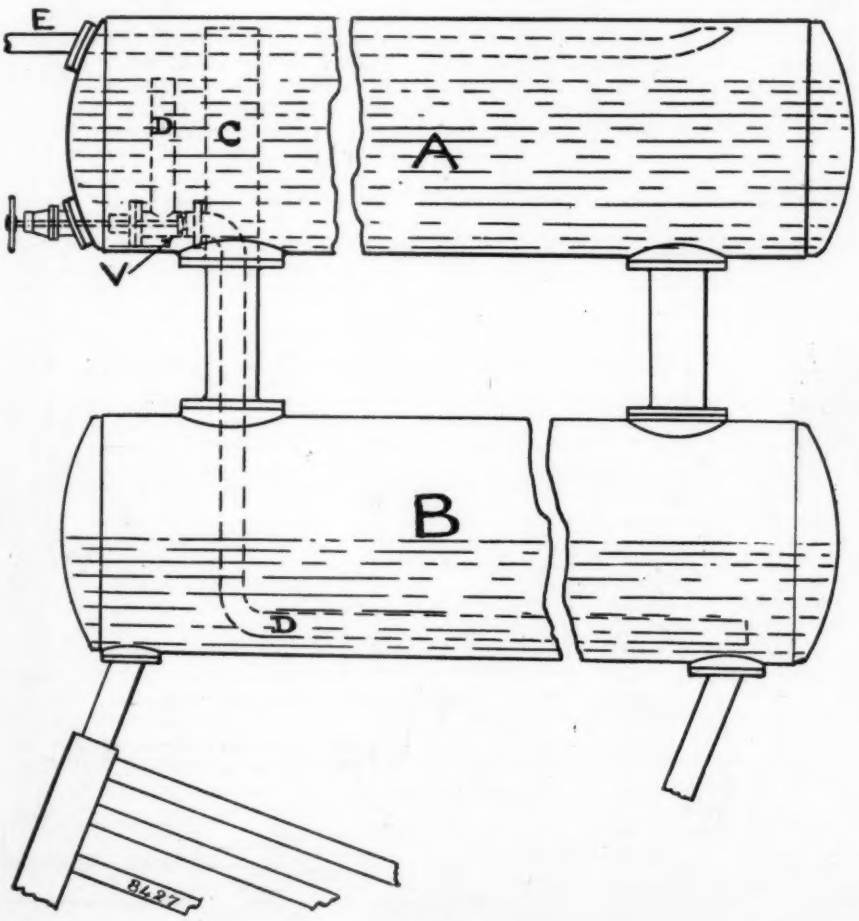


FIG. 3.

experiment has demonstrated the possibility of increasing the efficiency of a plant by its use, by as much as 20 per cent. under favourable conditions.

For example, on the Russian State Railways up to 1906, over 1,000 locomotives had been fitted with thermal storage tanks, and an elaborate series of tests showed an additional economy due to their use of 23 per cent. when burning coal, and 26 per cent. when burning oil fuel. Tests of six standard tank locomotives on the Lancashire and Yorkshire Railway, fitted with storage tanks 12 ft. 2 in. long by 3 ft. 2 in. diameter, and having a capacity of 420 gallons, showed an additional economy due to the system of 4 per cent. under all conditions of running, while where the nature of the road or the frequent stoppage of trains favoured the system, this gain rose to as much as 12 per cent.*

* *Proceedings Institute Mechanical Engineers*, 1906.

Tests by Professor Unwin some years ago, on a stationary boiler, showed an increased efficiency of over 19 per cent., while in the case of one stationary plant, shown diagrammatically in Fig. 4, the equivalent evaporation from and at 212° F. per lb. of coal rose from 10·02 lbs. with feed water going directly into the boiler at 191° F., to 11·94 lbs. with feed water entering the storage tank at 191° F., and thence entering the boiler at 307° F.

The chief advantage of the system, however, consists not so much in the increased efficiency, as in the increased capacity of the plant, when working on variable loads, which is rendered possible by its use. Thus at the Shoreditch Electric Light and Power Station, a storage tank 30 ft. by 8 ft., holding 9,000 gallons of water, was added to a battery of five Babcock and Wilcox boilers with a normal evaporative capacity of 20,000 lbs. per hour, with the result that 28,000 lbs. per hour were

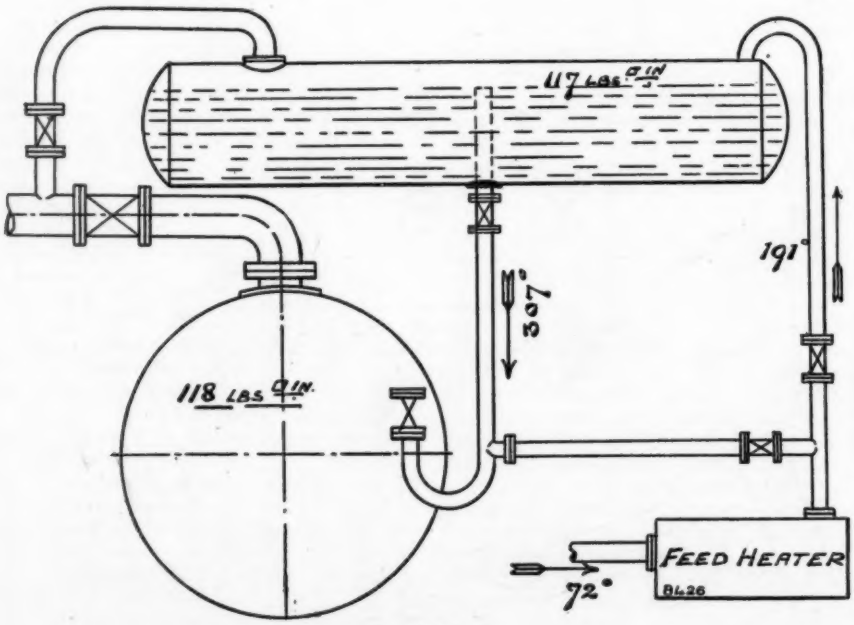


FIG. 4.

evaporated with ease at the peak of the load. A still more striking instance is afforded at the Wood Lane Electricity Works, where Babcock and Wilcox boilers, having a normal output of 12,000 lbs. per hour with feed water at 150° F., are reported as giving from 30,000 to 36,000 lbs. per hour when using the thermal storage tank.

The reason for this increased capacity under peak loads of short duration will be more evident if the method of working be briefly outlined.

At light loads, cold feed water is pumped into the storage tank at a rate largely in excess of that at which steam is being delivered to the engines. As much of this as is required to keep the boiler level constant is drawn from the tank by the outlet valve *V* (Fig. 3), and the rest accumulates until the tank is full to the overflow *D*. The feed pumps are then regulated so as to keep the tank full until the heavy load comes on, when they are stopped and all boiler feed is drawn from the tank at approximately boiler temperature.

Evidently, then, the heat to be abstracted from the furnace per pound of steam passing to the engines during the period of overload will be less than that corresponding to the total heat of formation of the steam, although at light loads it will be considerably greater, and this, to a large extent, accounts for the increased capacity.

For example—to take the case of the Wood Lane Station—at 210 lbs. pressure, with feed at 150° F. pumped direct into the boiler, this would have to supply 1083 B.T.U. to evaporate each pound of water, while with water at boiler temperature (391° F.) supplied from the storage tank, only 836 additional B.T.U. would be required. If, then, this were the only cause tending to alter the capacity of the boiler, this should be increased in the ratio $1083 : 836 = 1{\cdot}3$. A lowering of pressure, and hence of temperature during overload, would render available a further store of energy, which, on the assumption of a peak load of one hour duration, during which the pressure falls to 190 lbs., would amount to about 3 per cent. of the total energy of evaporation, so that an increased capacity of, say, 33 per cent. is readily explained. Actually, however, the increase was much more than this, and is evidently not to be accounted for wholly in this way.

If, however, the additional efficiency of evaporation, due to the fact that feed at boiler temperature is now being used, be taken into account, the increased capacity becomes easily understood.

In such a case as instanced, several minor causes undoubtedly also contribute to increased efficiency of working. In the first case, all blowing off at safety valves at light loads is prevented, and easier firing at the peak is permissible, with the result that less heat is given to the boiler brickwork and so lost by radiation. Also, priming is largely prevented by the increased uniformity of working of the boiler, a factor which is of great importance in most boilers of the water-tube type.

When thermal storage is used in normal working, the amount of heat to be given to the boiler per lb. of feed water evaporated will be unaffected by the presence of the storage tank, which now becomes a simple live steam feed heater.

The author obtained the first portion of his practical experience with the firm of Messrs. Pollit and Wigzell, Ltd., of Sowerby Bridge, with whom he spent seven years. This was supplemented by further experience in the drawing offices of the Milwaukee works of Messrs. Fraser and Chalmers, Ltd., which was followed by a three years' course in Engineering in the Victoria University of Manchester, terminating in his graduation with the first class honours degree of that University.

Electro-Magnetic Lifting Appliances.

THE electric lifting magnet, one of the most practical and efficient labour-saving devices, will no doubt be more extensively used in the future, both in this country and abroad, as the rapid introduction of electrically operated machine tools, electric cranes, and other motor driven machinery, insures an abundance of electric current for operating these and any other appliances which may be brought out in order to save time and labour in detail operation. Most iron and steel works, as well as all large machine shops and foundries are now provided with an electric central power station of greater or less capacity, which not only supplies current for operating motors about the shops and works, but also supplies the necessary lighting service as well.

The laws governing the operation of electro-magnets have been well known for years, yet the manufacturers of lifting magnets for commercial purposes is still an infant industry. The number of commercial magnets actually in use to-day is relatively small, taking into consideration the large number of plants which could profitably employ lifting magnets for handling various forms of raw metals and finished parts entering into the products of their manufacture. This condition is doubtless in a large part due to the fact that the advantages of lifting magnets are not generally realised, for it is worthy of note that probably no concern that has given the lifting magnet a fair trial has returned to the old method of handling iron and steel.

Wherever pig-iron, metal plates, tubes, rails, beams, scrap or heavy castings of iron or steel are handled, lifting magnets can be advantageously employed. The saving in time in adjusting hoisting tackle to the object to be raised is of itself oftentimes sufficient to justify the installation of a lifting magnet, while in the case of pig-iron, plates, rails and scrap, the practical advantages of lifting magnets are still more obvious owing to the large number of pieces that can be handled at a single lift, and to the fact that the objects so handled need not be piled beforehand. All that is necessary in work of this sort is to lower the magnet on to the objects to be handled, switch on the current, and lift. A further advantage of lifting magnets is found in the fact that metal too hot to be touched with the fingers can be handled as easily as cold metal.

It is claimed by those operating lifting electric magnets that a load may be picked up in an exceedingly short time, only two or three seconds being required for sufficiently magnetising the lifting magnet, and the saving thus made allows a greater output for each crane, so that fewer are required to do the same amount of work. While there is said to be a greater consumption of power the amount of current used is so insignificant as to be hardly worth mentioning. An electric lifting magnet which is capable of sustaining 2½ tons, according to some authorities, requires about 750 watts.

Various forms of material require various forms of magnets. The construction of magnets for handling plates, or material of a similar nature, affording opportunity to secure an intimate magnetic contact, is a comparatively simple problem. In such cases the principal care of the designer is to provide means for securely anchoring and properly insulating the magnetising coil. Calculations as to the lifting capacity of such a magnet can be made with considerable accuracy, as the total flux is easily figured.

Magnets for handling billets, rails, &c., laid in piles are, as a rule, operated in pairs. Such material, usually in

30 ft. lengths, is most conveniently handled by two magnets placed about 18 or 20 ft. apart on a balancing bar to which the crane hook is attached.

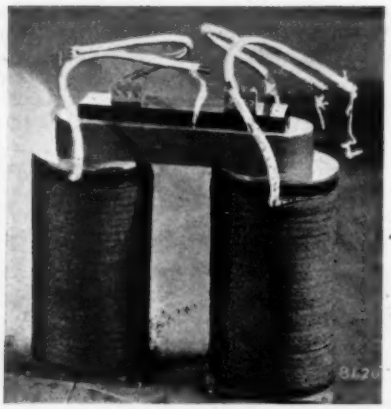
Magnets for handling pig-iron, scrap, &c., present the greatest difficulties in design. Such magnets are expected to handle a wide range of material, varying in form, in magnetic permeability, and often encountered in irregular piles, hence the reluctance of the magnetic circuit, and consequently the total flux will vary with each lift. This makes accurate calculation of total flux almost impossible, and experience absolutely essential to the production of a thoroughly good magnet.

By a good magnet is meant one which will lift, in proportion to its own weight, the greatest possible amount of material. The weight of the magnet itself must be considered as dead weight, and the aim of the manufacturer, therefore, is to construct a magnet that will combine a minimum of weight with a maximum lifting capacity.

Other things being equal, the larger the magnet the greater its lifting capacity. It is in this connection that the crux of the magnet problem occurs, for only the most intimate knowledge of electro-magnetism combined with practical experience in building lifting magnets will enable one to know the exact point at which any further saving in weight will be accompanied by a more than corresponding degree of efficiency.

GERMAN ELECTRIC LIFTING MAGNETS.

While it is true that the weight of the magnet itself must be considered as dead weight, still it may sometimes happen that, as between two magnets, the heavier may actually be the more economical of the two. The material handled by lifting magnets is seldom simply hoisted—it is hoisted and conveyed. While the power required to



EARLY FORM OF ELECTRIC LIFTING MAGNET.

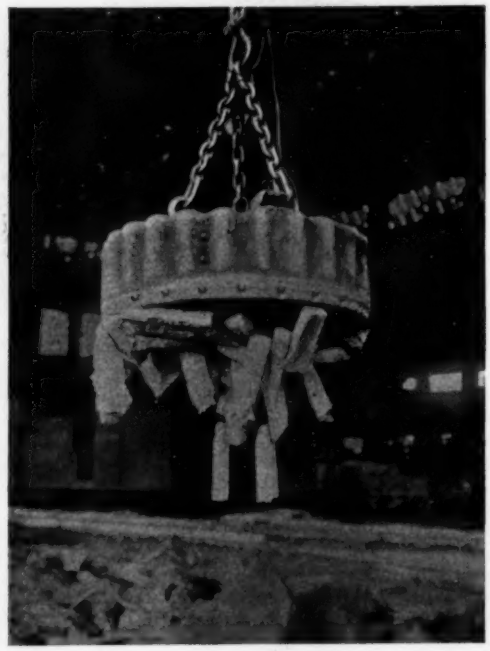
hoist is directly proportional to the load on the crane hook, this does not hold true with regard to conveyance, for the weight of the crane itself forms so large a proportion of the total load to be moved along the track, that a larger dead weight, which by lifting more, will reduce the number of trips made by the crane, may show a marked saving both in time and current consumption.

The accompanying illustrations show the details and method of operation of types of this lifting-crane, the first showing the method of lifting angle iron in a German iron and steel works. Hooks, it will be noticed, are provided for use if necessary, ensuring against the dropping of the material in case the current should for any reason be shut off.

These magnets are capable of retaining a maximum load of 2,000 kgs., and the crane has a hoisting speed of 15 metres per min. The trolley travels at the rate of 45 metres per min., and the crane itself at a speed of 100 metres per min. Three-phase alternating current of 400 volts pressure is used for operating the crane motors, while the lifting magnets are energised by 230-volt direct current supplied from a rotary converter.

The electrical works of the Compagnie Internationale D'Electricite, Liège, are manufacturing a lifting magnet for use in rolling mills, foundries, and iron and steel works.

Two types of lifting magnets are constructed, the single and the double, the latter being simply composed of two of the single type magnets, one fixed at each end of a beam, which is suspended at the centre from the crane hook. The "International" electro lifting magnet consists of two parts, an outside bell-shaped cover and the magnet proper or coil. The cover is utilised to protect the inside mechanism from any shocks which might occur, and also allows it to be used in the open air without danger.



LIFTING MAGNET HOLDING MANGANESE CAST IRON.

MAGNET LIFTING STEEL STAMPINGS.

The magnet can also be employed for lifting very hot pieces of metal, thus making it especially useful in foundries and rolling mills. The current is supplied by two conductors placed along the length of the crane, the connection being made by contact pieces attached to the crab.

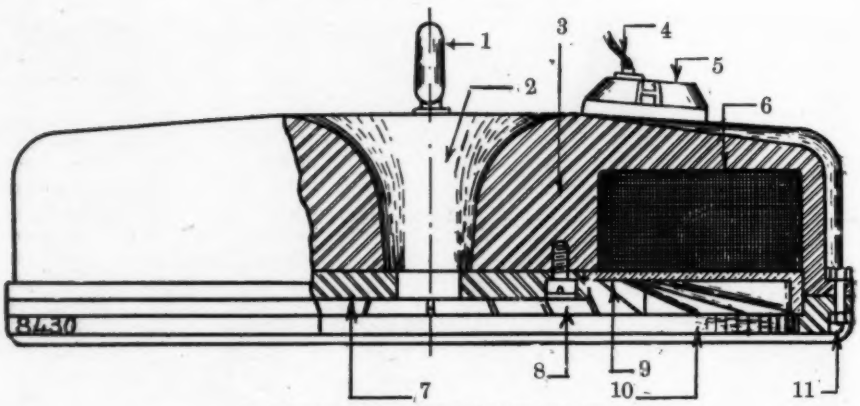
In the United States lifting electro-magnets have been utilised for several years, and a number of different types have been developed for handling plates, rails, and castings and foundry productions, and for use in scrap iron yards and machine shops, which have given much satisfaction.

The engineers of the Cutler-Hammer Clutch Co. of Milwaukee, who may be said to have specialised in problems involving electric and magnetic control, have devised a lifting magnet embodying several new features. In the design of this magnet the magnetic attraction of the inner pole has been purposely made stronger than that of the other pole. The practical effect of this concentration of the magnetic flux on the inner pole, is that in handling iron pigs or similar material, the various pieces constituting the load are released by the outer pole first, when the current is switched off, and are drawn towards the centre of the magnet by the superior attraction of the inner pole, thus enabling the operator to deposit the load within an area scarcely exceeding in radius the diameter of the magnet itself.

Every prospective purchaser of a lifting magnet naturally wants to know the amount of current consumed that he may be able to intelligently calculate the saving that may be reasonably expected in handling material with this labour saving device.

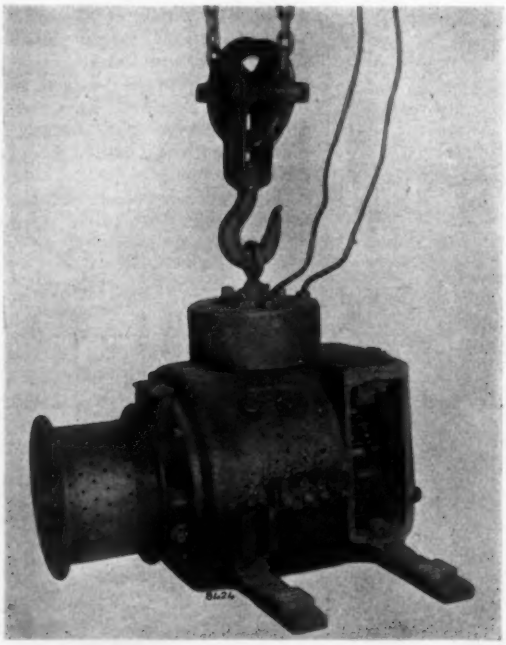
The following data obtained during the test of a 52-in. "Cutler-Hammer" magnet at

10.-IN. MAGNET LIFTING THREE BOILER PLATE HEADS.



DETAILS OF "CUTLER-HAMMER" LIFTING MAGNET.

1 Eye bolt.
2 Central flue permitting heat radiation through body of magnet.
3 Magnet body.
4 Cable.
5 Terminal box.
6 Coil.
7 Inner pole shoe.
8 Pole shoe retaining screw.
9 Coil shield.
10 Outer (removable) pole shoe.
11 One of the through bolts fastening removable pole shoe to magnet body.



ELECTRO MAGNET RAISING TRAIN LIGHTING DYNAMO.

a sheet and tube works throws light on this point:—

Total weight of pig-iron unloaded, from steel gondola wagon, 109,350 lbs.
Weight of average lift, 739 lbs.
Number of trips required to empty wagon, 139.
Current on magnet, 1 hr. 15 min.
Current off magnet, 50 min.
Total time consumed, 2 hrs. 5 min.
Current required, 30 amperes at 220 volts.

From the foregoing figures the cost of operation is easily calculated, assuming the cost of current to be $1\frac{1}{2}d.$ per kilowatt hour, which is probably in excess of cost of current in large commercial plants.

Thirty amperes at 220 volts corresponds to a power consumption of 6,600 watts which was required for 1 hour and 15 minutes. This gives a total power consumption of 8·25 kilowatt hours, which at $1\frac{1}{2}d.$ per kilowatt hour gives a total of little less than 1s. $0\frac{1}{2}d.$—cost of current for energising the

magnet during the period required to unload 54 tons of pig-iron.

That the commercial applications are not limited to lifting magnets is indicated by the fact that at the Maryland Steel Co. two specially designed "Cutler-Hammer" magnets are used for separating iron from coal.

In the ordinary run of mine coal pieces of iron, such as spikes, cable-pins, broken pick heads, &c., frequently find their way into the chutes, with disastrous results to the coal crushing machinery. To avoid such mishaps magnets are now employed. At the above-mentioned plant the run of mine coal is carried about 25 ft. above the ground level by means of a conveyor, and allowed to pass down a chute, from which it is discharged into a second chute. The magnets are placed in an opening between the upper and lower chute, and cause any piece of iron which may be mixed with the coal to be deflected sufficiently to prevent them from passing into the chute which feeds the coal into the crushers.

Electric Tramway and Railway Development at Buenos Aires.

THE LACROZE TRAMWAY SYSTEM AND THE FERRO-CARRIL CENTRAL.

Buenos Aires, which was founded in 1535, had in the year 1870 a population of some 180,000 inhabitants. To-day, according to official statistics, the population within the city limits exceeds 1,100,000. The rate of increase, due to natural causes and to immigration, amounts to doubling every thirteen years. In a period of five years, the increase is equivalent to the whole of the population of a large capital like Lima.

After Paris, Buenos Aires is the largest Latin capital of the world, and by reason of its many fine buildings, its splendid avenues and parks, and the organisation of its public services, lays a very strong claim to be called the Paris of South America.

Like most cities of relatively recent creation in the new hemisphere, Buenos Aires has had the advantage over older historical European cities, inasmuch as it has benefited, free of all experimental costs, by the latest improved inventions connected with public works. At the same time, however, it must be recognised that the citizens of the Argentine capital have been very much alive to the possibilities of modern engineering and modern business methods, and the marvellous progress of the city is due to their foresight and energy.

Among the public works of note may be mentioned the port, with its four large docks for Transatlantic steamers, thoroughly up-to-date drainage and water supply systems, and extensive railway networks connecting the capital with the fertile plains of Argentine and with the seashore, and interconnecting the eastern part of Argentine by inter-continental routes with Chile, Bolivia, and Paraguay. In addition there is a large development in electric lighting and electric tramway undertakings. In fact, one of the greatest difficulties has been the meeting of the constantly increasing requirements of the rapidly growing country and capital for all kinds of public services. For instance, the port works, which were built but a few years ago, and were considered at that time amply large for many years to come, have been so congested of late that many hundreds of thousands of pounds have been lost to shippers and to the trade in general. However, at the present time, a new scheme for considerable enlargements, involving an outlay of £5,000,000, is being actively pushed forward. Furthermore, the building of new approaches for the railways and of new stations, the paving of considerable extensions of new streets, the supply of drainage and water for large new areas, the

increase of electric lighting and the development of the telephone systems, are all now in full swing. The transportation of the populace within the city, and from the city to the suburbs, is also meeting with due recognition. That the traffic within the city itself is of great magnitude is proved by the returns of last year, which show a movement of over 200,000,000 passengers by the tramways alone. This great movement is explained by the considerable area covered by the city, which is equivalent to not less than two-thirds of that of London, and consequently greater than that of large cities like Paris, Berlin, Glasgow, Hamburg, Genoa and Vienna. Due to this great extension, to the warm climate, and to the fact that the population prefers to ride even for very short distances, the needs of adequate transportation facilities have been particularly great. Even some years ago the horse tramway system was very considerably developed, amounting to some 280 miles. Owing to the disposition of the streets, which are on the American chessboard system, and to their narrowness, the tramway lines have been distributed all over the town in such a manner that practically not a single important street is without its line. In order to avoid congestion, the tramway traffic as a rule moves in one direction only. Every line, therefore, uses certain streets on its way out and different streets on the return journey.

In the early nineties it was evident to the tramway owners that horse lines were no longer capable of meeting the demands made upon them, and accordingly the first section of electric tramways was laid in 1897. Since that time practically all of the lines have been converted by various companies, mostly formed by English enterprise. The increased facilities afforded by electrification have, however, as usual, not diminished but increased the congestion. The municipality, in order to ameliorate the conditions under which transportation is carried on, has decided to construct a vast system of diagonal avenues and of street widenings, for the planning of which the services of the eminent French architect of the City of Paris, M. Bouvard, have been requisitioned. This scheme when carried out will cost many millions of pounds, and will change the whole aspect of the city.

Among the various tramway systems of Buenos Aires one of the most interesting is that of the Buenos Aires Lacroze Tramway Co., the only native Argentine tramway company in the city, and the only line running a high speed suburban service on American lines, with private right of way and cars equipped for a maximum speed of 50 miles per hour.

The Tramway Rural was formed in the year 1884 by one of the pioneers of tramway traction in Buenos Aires, Mr. Frederico Lacroze. The first line which he built ran from the Plaza de Mayo to the Plaza Il de Setiembre, which line he afterwards sold to the Anglo-Argentine, and has been the nucleus of the very large system now operated by that company.

With remarkable activity, Mr. Lacroze extended his system into the system of tramways until recently operating under the name of the "Rural Tramways," and in addition extended his lines many miles into the country, at a time when the other companies did not realise the importance of possessing adequate suburban communication.

The whole undertaking grew to a point when it became necessary to form two different systems, viz., "The City Tramway Lines," now known under the name of the "Buenos Aires Lacroze Tramways," and a steam railway line, extending from Chacarita Station in Buenos Aires to Salto and to Zarate, a total length of 220 k.m. This steam line, which for long was known as the "Tramway Rural à Vapor," has recently been organised into a new company called "Ferro Carril Central de Buenos Aires, Limitada."

One interesting point in connection with the original franchise was, that the same was granted to the concessionaire under the obligation of the exclusive use of horse traction. The reason given by the authorities for this stipulation was, that it was necessary to develop the national industry of the country, which at that time depended almost entirely upon horse breeding.

The original tramway was extended by degrees under the old concession for a distance of upwards of 100 miles into the country, and there can be no doubt that this line holds the record for long distance tramway service by horse traction, and, in addition, the "Rural Tramway" can boast of having been the first tramway to run a sleeping car over its lines.

At a later date the authorities recognised that, for the purpose of giving an efficient service, it was necessary to grant a permission to use mechanical traction, and for this purpose steam locomotives were employed.

The considerable development of the business of the "Tramway Rural" in the hands of Frederico Lacroze became at his death still more important in those of his active and energetic sons.

Their first step was to enter into a contract, in the year 1905, with Messrs. J. G. White & Co., for the reconstruction and electrification of the old city lines under the name of the "Buenos Aires Lacroze Tramways." Being laid in the new portions of the city, the streets are wide enough to accommodate a double track.

The work was commenced in March, 1906, and before the end of that year the new power house with a capacity of 2,250 k.w. was in running order,—an achievement which, considering the labour troubles and the port congestion, may well be considered a record for rapid construction. Part of the lines were opened formally to public traffic on the 10th March, 1907, and since that time the traffic receipts have increased beyond all expectation. The original lines consisted of 40 k.m. of track, owned by the company, and 10 k.m. held jointly with other companies and on lease.

Messrs. J. G. White & Co. are now engaged in extending these lines a further 40 k.m., the franchise for which was granted by the Buenos Aires Municipality in December, 1905, and for the purpose of serving these new lines, another 750 k.w. set is being added to the station.

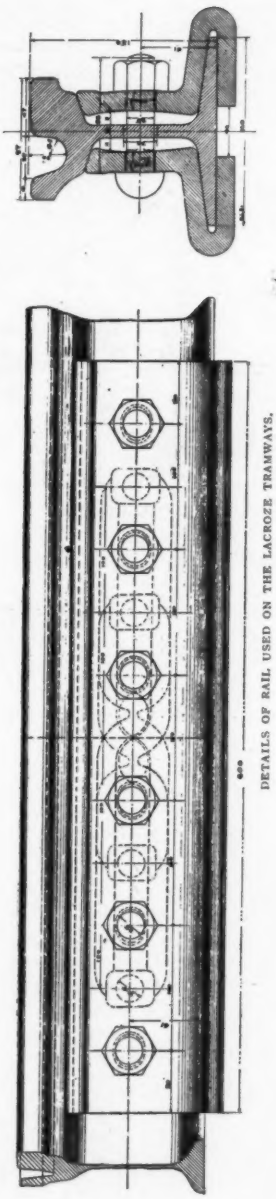
TRACK WORK.

All the lines are laid to a gauge of 4 ft. 8½ in. The rails, manufactured by the German Steel Works Agency, Phoenix Mill, and the Société Anonyme des Acieries d'Angleur, of Belgium, weigh 87 lbs. per yard. The first shipments were 45 ft. in length, but on account of shipping difficulties, later shipments were made in 40 ft. lengths. They have the following specified chemical composition :

Carbon from 0·45 to 0·55 per cent.
Manganese from 0·70 to 1·00 per cent.
Silicon not to exceed 0·10 per cent.
Phosphorus not to exceed 0·10 per cent.
Sulphur not to exceed 0·10 per cent.

A test piece, having a sectional area equal approximately to ½ sq. in. and with a length of 2 in. between test gauge points, was prepared and tested. The ultimate tensile strength was not less than 40 tons per sq. in., with an elongation of not less than 12 per cent. on a length of 2 in. The tiebar holes were punched, and all other holes were drilled.

The rails are laid on concrete stringers. The depth of the stringer is 6 in. and the width 16 in. The greater part of the paving has been executed with granite setts, the setts being rammed by the implement shown in the illustration, operated by four men.



DETAILS OF RAIL USED ON THE LACROZE TRAMWAYS.

VIEW OF THE TRACK WORK SHOWING METHOD OF RAMMING THE SETTS. LACROZE TRAMWAYS.

The tiebars are of the Bayliss, Jones & Bayliss pattern, 2 in. by ¼ in., spaced at intervals of 3 ft. 9 in. Continuous joints, supplied by the Continuous Rail Joint Co. of Great Britain, Ltd., were used, 24 in. long, weighing 77 lbs. per pair.

All the special work for the track was supplied by Messrs. Hadfield's Steel Foundry Co., Ltd., and the United States Steel Products Export Co.

The rails are bonded by two concealed bonds 4/0 B. & S. gauge. The gradients offer no difficulties, since the track is practically all laid on the level. The radius of the sharpest curve is 45 ft.

OVERHEAD EQUIPMENT.

The overhead equipment consists of side poles with span wire construction, centre poles, side pole construction with bracket arms, and a few rosettes. The poles are made, to the British Standard Specification, of steel, 30 ft. in length, in three sizes, and were supplied by Messrs. Stewarts & Lloyds, Limited.

The trolley wire is 2/0 B. & S. gauge, copper, with a height of 20 ft. 6 in. from the ground, and was supplied by Messrs. Edward Le Bas & Co. The section boxes were supplied by Messrs. Estler Brothers.

POWER HOUSE.

The power house is situated at the corner of Medrano and Cuyo, the buildings being of massive brick construction with an exterior plastering usual to the country. The buildings comprise an engine room, 58 by 17 metres; a boiler house, 40 by 9½ metres; and a coal storage of the same size, representing a total area of 1,806 metres, and with room for considerable extensions. A massive brick chimney has been built, its height being 47·50 metres.

In the engine room are installed three 1,100 i.h.p. horizontal cross compound engines by Carels Frères, Belgium, constructed after the "Sulzer" patent; these each drive direct a 750 k.w. compound wound D.C. generator by the General Electric Co., New York, U.S.A., giving 550 volts at 115 revolutions per minute. The consumption of the engines averages 22 lbs. of steam per k.w. hour with a load factor approximately 40 per cent. Each engine has its own condenser, of the "Contraflo" type, by Richardson, Westgarth & Co. The air

pumps are of the "Edwards" type, independently driven by steam engines supplied by Allen & Co. "Worthington" centrifugals are used for circulating pumps, each being capable of dealing with 1,000 gals. per min., and are driven direct by "Brown-Boveri" motors.

The switchboard is located at the end of the engine room, facing Cuyo, and is of the railway type by the British Westinghouse Co., and at the present time consists of fourteen panels, which comprise three generator, three negative booster, six feeder, a Board of Trade, and a lighting panel, the panels being of marble, and are equipped with all the necessary instruments for a safe and rapid handling of a large traction load. At the present time one 60-k.w. negative booster by the E.C. Co. is installed. A 25-ton crane by Carrick & Ritchie traverses the engine room.

The water for condensing purposes is cooled by two natural draught cooling towers, which are of wood, the interiors being supplied by Richardson, Westgarth & Co., whereas the materials for the shells were procured locally, each tower being capable of cooling 66,000 gals. per hour.

In the boiler house are installed, with room for extensions, five marine type boilers by Babcock & Wilcox. These are fitted with their well-known superheaters, having a heating surface of 630 sq. ft. Each boiler is capable of evaporating 12,000 lbs. of water per hour, the grate area and heating surface being 49 sq. ft. and 2,480 sq. ft. respectively.

The three feed pumps installed are of the "Worthington" duplex type. A "Wheeler" feed water heater capable of utilising all the steam from the auxiliary plant is installed, and there are also a "Paterson" condensation water purifier and grease eliminator.

In the coal store an electrically operated overhead "Temperley" transporter with a Hone's grab has been fitted, and in the power-house yard there is an "Avery" 20-ton weighbridge for coal weighing purposes. The water supply is taken from a well on the premises, by a treble-barrelled deep well pump, electrically driven, by

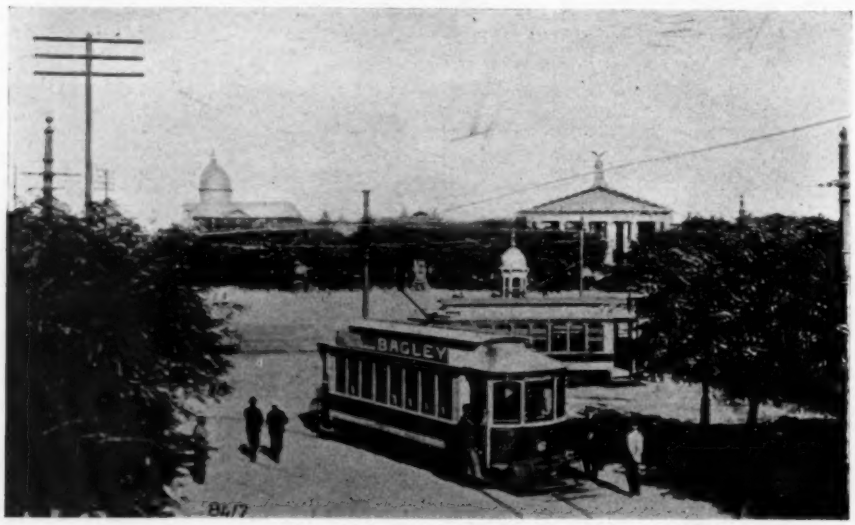
VIEW OF THE ENGINE ROOM: LACROZE TRAMWAYS POWER HOUSE.

Hayward, Tyler & Co. A supplementary supply can also be taken from the city supply. The feeders have been supplied by Callender's Cable and Construction Co., Ltd., and are paper insulated, lead covered, and are drawn into Sykes' patent stoneware conduits.

There are three car-sheds, one being at Medrano, alongside the power house; the other two are respectively at Chacarita and Palermo. The rolling stock for city purposes will consist of 140 cars of the semi-convertible type, the cars being supplied by the J. G. Brill Co. Their construction allows the car to be completely shut in during bad weather, whilst at other times it is practically an open car. There is seating accommodation for 32 persons; the seats are upholstered in cane. The tops of the windows on each side of the car are made in accordance with the "Brill" patent. The glass of the windows is of good quality and set in rubber. The car doors are of the mutually operating double sliding type. The platform at each end of the car can be entirely closed if desired; it is in the form of a vestibule, having three drop windows in front and two-leaf folding doors on either side, as well as a sliding metal gate. The roof is of the monitor deck pattern, with eight ventilator sashes on each side and operated by four ventilator openers, one in each corner of the car. Two electric fans are also fitted, and the cars are well lighted. The wood employed inside for the doors, linings and mouldings is mahogany, while the ceiling is decorated with three-ply birch veneer. The cars are tastefully painted cream and green outside, with trimmings of solid bronze. The electrical equipment comprises two 40 h.p. motors supplied by the British Westinghouse Co., capable of maintaining a speed of 15 miles per hour.

In addition to the City cars, there will be at first ten interurban cars, the only difference being that these are larger, seating 44 people, and that the electric equipment comprises four 50 h.p. motors. With these it will be possible to maintain a speed of 40 miles per hour. These cars will operate on the city lines, passing on to the steam line at Chacarita, and running through Lynch to the important suburb of San Martin.

Electric locomotives will also be used in connection with the heavy goods department, a large and increasing business. Dick, Kerr & Co., Ltd., are supplying the locomotives, the type used being the central cab, mounted on two 4-wheeled bogies, the electrical equipment comprising four 50 h.p. motors, capable of hauling a train of 50 tons at 20 miles per hour. These



BUENOS AIRES LACROZE TRAMWAYS: CITY CARS.

BUENOS AIRES CENTRAL RAILWAY: GANG AT WORK TRANSPORTING EARTH ON ZONES FOR EMBANKMENT.

BUENOS AIRES CENTRAL RAILWAY: CHACARITA STATION AND CEMETERY FROM THE EAST.

locomotives will haul the freight trains of the F.C.C.B.A. and the Entre Rios Railway from Chacarita to the goods station at Once and to the market.

Mr. C. E. d'Ornellas acted as superintendent in charge of the above work for Messrs. J. G. White & Co., Ltd.

Ferro Carril Central de Buenos Aires.

FORMERLY TRAMWAY RURAL A VAPOR.

The F.C.C.B.A. is a railway of 4 ft. 8½ in. gauge, extending westward and north-westward in the province of Buenos Aires, from Chacarita Station in the city of Buenos Aires to the town of Salto, a distance of 174 k.m., with a branch 44 k.m. long to Zarate, a town on the Paraná river, and a branch of 3 k.m. from Lynch to the suburb of San Martin. It traverses one of the most fertile districts in the Argentine.

The history of the railway is believed to be quite unique, in that it was constructed as an extension of an urban horse tramway from the surplus earnings of the latter, and was operated as a horse tramway for goods and passengers for a considerable distance in a then thinly settled country. In 1884, Don Frederico Lacroze, whose horse tramway was the pioneer among the street railways of Buenos Aires, and who already owned at that time an extensive system in the city, obtained a concession to build the "Rural Tramway," to start from Chacarita, then the most westerly point on his lines. Buenos Aires province is one of those regions where it is cheaper to build a railway than a good road. Sr. Lacroze saw the opportunity for supplying transportation much cheaper and much more rapid than then existed, to a large, fertile, and rapidly developing agricultural zone.

Construction proceeded as fast as earnings became available for that purpose. From 1885 to 1892, 97 k.m. of main line, the San Martin branch of 3 k.m. and the Zarate branch of 44 k.m. were built, a total of 144 k.m. From 1892 to 1895 the main line was extended to 133 k.m., and by 1897 the present system of 221 k.m. was entirely in operation. The early type of construction was necessarily very economical, the rails weighed 30 lbs. to the yard, the sleepers were creosoted yellow pine 2 m. long, and the bridges were supported by wooden stringers. Earthwork was avoided as much as possible, the track being laid practically upon the ground.

It became evident as early as 1891 that it would be necessary to introduce steam traction in order to cope with the traffic. Accordingly eight 16-ton saddle-tank engines were bought from the H. K. Porter Co., Pittsburg, U.S.A., and bridges were strengthened to receive them. With the earnings of these eight locomotives, supplemented in 1896 by three 18-ton passenger locomotives, the railway was rapidly developed, gradients were reduced, rolling stock purchased, a handsome new passenger station built at Chacarita (the Buenos Aires terminus), the large and modern fire-proof goods station built near the Plaza Once, in the heart of the city of Buenos Aires, 50 k.m. of line relaid with 50 lbs. rails, and the 47 k.m. extension from Salto to Rojas begun.

The F.C.C.B.A. is at present in transition from a light railway to a standard heavy railway. This is appropriately marked by its being transferred in July, 1906, by Messrs. Lacroze Bros. & Co. to a new public company, the Ferro Carril Central de Buenos Aires, the old name of Tramway Rural à Vapor disappearing.

This period of transition, an inevitable phase in the development of so highly favourable an enterprise, may be said to have been occasioned by the agreement with the Entre Rios Railway. The latter, founded as a provincial Government railway in 1883, now an English company, operating some 480 miles of 4 ft. 8½ in. gauge line, has always been a purely local enterprise, being segregated from the city of Buenos Aires, as well as from the rapidly developing provinces of Buenos Aires and Santa Fé by the immense Paraná River, which interposes, not only its own enormous width, but also a belt of swampy delta land 35 to 40 miles wide, as a barrier along the entire western and south-western sides of the province of Entre Rios. Similarly, the northern connections of the Entre Rios Railway, the East Argentine Railway, 99 miles, and the North-East Argentine Railway, 411 miles, all of the same standard gauge, are entirely separated from the rich central provinces of the Republic.

An extension is also under construction from Santo Tomé, the extreme north-eastern point of the N.E. Argentine, northward to Posadas, where, by transfer across the Alto Paraná to Villa Encarnacion, it will connect with the 250 miles of the Paraguay Central Railway, also of the same 4 ft. 8½ in. gauge. Thus, there was a system of railways, present and prospective, of about 1,400 miles, awaiting an entrance into the province and city of Buenos Aires. Under these circumstances, the Entre Rios

Railway made a contract with the F.C.C.B.A., by which the former will deliver its trains to the F.C.C.B.A. at Zarate, whence the latter will haul them to Buenos Aires.

Extensive works have been undertaken for carrying out this programme and are now well under way. The Entre Rios Railway is extending its lines to Ibicui, a point on the Paraná delta opposite Zarate. There, it is building a port and ferry slip, and at Zarate it is building another ferry slip; between these points will ply a large steel transfer ferry boat, with a capacity of about thirty goods waggons.

The ferry boat for this service was built in Scotland, and proceeded to the Argentine under her own steam, arriving in May. From the ferry boat at Zarate, the Entre Rios Railway is building a connecting line up to the top of the bluff, where it joins the F.C.C.B.A. The latter is reconstructing its entire permanent way between Buenos Aires and Zarate, 101 k.m., using new hardwood sleepers of full size, closely spaced, and 70 lbs. rails.

Partly in connection with this general plan of reconstruction, partly as an outgrowth of the recent electrification of the Lacroze City Tramways, the F.C.C.B.A. is reconstructing its short branch to the large suburb of San Martin, and is equipping the entire line from San Martin to Chacarita terminal (about 11 k.m. of double track) for a high speed electric service, which will be operated by the Tramways Company. By a contract with Lacroze Tramways Company, dated 29th March, 1906, running powers were granted over the lines of the latter company from the Chacarita Station to the goods station at the Once, and to the Mercado de Abasto Proveedor, the Covent Garden of Buenos Aires. The engineering and construction work entrusted to Messrs. J. G. White & Co. Ltd. in connection with this railway, consists of about 100 miles of main line laid with 70 lb. "Vignole" rail on quebracho sleepers, and about 16 miles of sidings and yard tracks with lighter rails, also the necessary waiting and goods sheds and stations to be erected. The longest bridge is 60 m. in 3 spans: 2 of 10 m. and one of 40 m. The Lynch repair shops situated at Lynch, about midway between Chacarita and San Martin, are being entirely re-modelled, and fitted with up-to-date machinery. They will consist mainly of a machine and erecting shop, a smithy, a foundry, and a carpentry and paint shop. Complete buildings for general stores will be erected, as well as the necessary storage accommodation for locomotives, and rolling stock, distributing yards, &c.

The F.C.C.B.A. has secured from the National Congress a concession for a further extension from Rojas north-westwards to Villa Maria, about 300 k.m., and a further application has been made for a concession to build a small port at Zarate.

Friction and Lubrication.

By J. T. NICHOLSON, D.Sc.

THE contemplation of a world without friction exercised for a moment the imagination of Dr. Nicholson at the opening of his recent address on the subject of Friction and Lubrication, before a meeting of the Manchester Society of Engineers, on November 23rd last. The instantaneous removal of friction, he said, would mean the death of every living creature in the course of a few minutes. Everything in motion would persist in the same direction with the speed it had till it collided. Everything lying at rest upon a level surface could never begin to move. Wind would have no effect upon the sails of ships, nor would the propeller of a steamer have any power either to start or stop it.

Every loose object on a slope of the earth's surface would slide down to the lowest point and on up the opposite side till it attained its initial elevation, when it would commence a return journey.

Although what would happen in the second five minutes is like the song the Syrens sang, "Not beyond all conjecture," there is nevertheless wisdom in Dr. Nicholson's suggestion of leaving the genius of a Mr. H. G. Wells to predict the consequences. Although, in his paper, Dr. Nicholson does not advance many new facts, his utilisation of the results

obtained by Stribeck, Dettmar, Heimann, Lasche, Beauchamp Tower, Thurston and others has been admirably utilised for the obtention of formulæ which give a better approximation to practical requirements of the most divergent kinds than has hitherto been obtained. In particular, the view commonly held that the length of a bearing should increase in proportion to the speed is shown to be erroneous. Descriptions of some of the modern methods of automatic and forced lubrication are given. The theory of the action of the loose ring and of the fast collar, as also that of the sizing of bearings for forced lubrication, have not been undertaken. The following is the first or theoretical portion of the paper.

Dry Friction.—In this case one solid substance rubs upon the other without the intervention of any unguent.

The resistance offered to relative motion is then due either to absolute abrasion, or, if this is insensible, to molecular interference between the two surfaces.

However smooth a metallic surface may appear to be to the eye, its real condition in this respect as it would appear if viewed with a microscope of "double million magnifying power" (to quote Sam Weller) resembles that of a most terrifying rugged mountain system.

The peaks and chasms on the two surfaces are crashing into and over each other when there is relative movement. The molecules also are in a state of constant vibration about their mean positions, and even if the mountain peaks be not torn off by the relative movement, the intermingling of the molecules of the two opposing bodies exercises a resisting force by reason of the interchange of their momentum. That such a process should be reducible to any regular system of laws is not to be expected. A complete molecular theory of matter would be required to rationalise the phenomena which occur.

There are certain rough generalisations, however, which are useful to the engineer. Thus:—

(1) Within certain small limits the frictional resistance may be said to be roughly proportional to the load acting; or to be independent of the extent of the surface over which that load is distributed; but when the pressure or load per square inch is large the friction increases at a greater rate than the load; or in other words the coefficient of friction increases with the pressure.

(2) The coefficient of friction varies with the speed of rubbing. It is greatest when the motion is slowest; and when one body is just commencing to move relatively to another we have what has been aptly termed "stiction" or the "friction of repose."

Rennie investigated this point in 1829 and obtained values for the coefficient of "stiction" of from 0·3 to 0·4 for iron upon iron.

For moderate speeds Morin in 1837 found the coefficient of friction to vary from 0.15 to 0·25 for iron upon iron.

For speeds from 10 to 90 ft. per sec. the experiments of Bochet, Poirée and Capt. Galton gave coefficients of from 0·2 to 0·1 respectively.

Lastly for the slowest speeds Ewing and Fleeming Jenkin found that the coefficient of friction of motion merged continuously into the coefficient of friction of repose.

(3) The mutual friction of solids with no unguent interposed was found by Galton to diminish as the temperature increased. This is due to the fact that abrasion is easier at high temperatures. As compared with the internal frictional resistance to relative motion offered by liquids and gases, we find that this diminishes for the liquids and increases for the gases, as the temperature rises. Paradoxical results like these can be satisfactorily explained only by reference to the kinetic theory of liquids and gases, which is beyond our present purpose.

Greasy Friction.—When some unguent is placed between the bodies, it may easily be imagined that some of the valleys are levelled up, and the intensity of the molecular action on the mountain tops is diminished. Thus we may have in this case any value up to that for dry friction. For iron upon iron, greasy and polished, Morin obtained the value 0·15 for the coefficient.

In the case of a greasy shaft lying in its bearings at rest, we find that the brass, being somewhat larger in bore than the diameter of the journal, is touched by the latter only along a narrow line at its lowest point. If now rotation begins, the journal rolls up the slope, just like a wheel, until the load on the bearing—supposed vertical—makes an angle equal to the maximum angle of repose ϕ with the journal radius drawn to the point of contact. The point of contact K (see Fig. 1) is then in a plane distant $r \sin \phi$ from that containing the centre of the bearing, and the journal slides on this point, or rather line, with the three forces f, n, and W in equilibrium. The law followed is that of so-called "dry

friction," and the coefficient of friction $\mu = \tan \phi = \frac{f}{n}$ is identical with that found by Morin in 1833 for slightly greasy metallic surfaces, viz., from 0·12 to 0·18—or say, 0·15 on the average.* The ratio $\frac{f}{W}$ is, of course, equal to sin ϕ, and being nearly the same as tan ϕ for such a small angle—8½ degs. —we have, for the frictional work done per revolution—

$$\text{Friction work} = \frac{2\pi rf}{12} = \frac{\pi d \mu W}{12} \text{ ft.-lb./rev.}$$

This is true even when there is plenty of oil, so long as the speed is small.

Take, as an example, the case of a spindle for a 10 in. lathe running slowly with a weight of 3,000 lbs. carried by the front bearing, which is 3½ in. diameter. Then the friction work per revolution is 0·15 π × 3·5 × 3,000/12 = 413 ft.-lbs. per revolution.

If the cut were ¼ in. × $\frac{1}{16}$ in. on soft steel, the cutting force would be 3,500 lbs., and on a job of faceplate diameter (20 in.) the useful work spent in cutting per revolution would be $3{,}500 \times \frac{20\pi}{12} = 18{,}300$ ft.-lbs.

The work lost in friction at the front journal is therefore $\frac{413 \times 100}{18{,}300} = 2{\cdot}26$ per cent. of the useful work.

A similar calculation for a lathe of 48 in. centres would show a loss of about 10 per cent.

Such great frictional losses which are constantly and inevitably happening when a lathe spindle, or other rotating shaft, runs slowly, even when abundantly fed with oil, impress upon us the necessity for using measures to preserve a separating film of grease or oil between journal and bearing, and not to allow them to run in metallic contact. This is much more difficult to accomplish at slow than at high speeds.

Fig. 2 shows the position of the point or line of contact between shaft and bush when the force acting has any other position, such as that shown by *P*. This position may always be found by drawing the resultant force from the journal or bearing as a tangent to the friction circle, of radius $r \sin \phi$, in a sense tending to turn it in the direction of rotation.

ACTION OF A LUBRICANT AT MODERATE SPEEDS.

When, as shown in Fig. 1, the load on a journal acts vertically downwards and the point of contact is at first at *K*, Fig. 1, near the bottom, there comes a time as the spindle speed goes on increasing when the oil is carried round with the journal, and forms a film separating it completely from the bush. The point of nearest approach between journal and brass is by this means shifted round to *B*, at the back of the bush, and in the same horizontal plane as the centre—see Fig. 3.

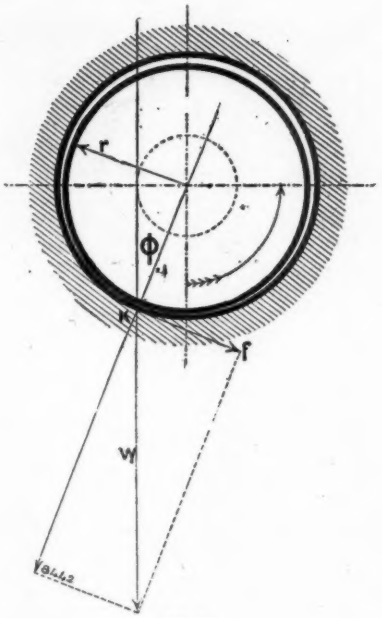


FIG. 1.

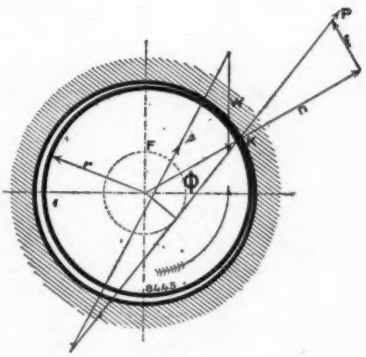


FIG. 2.

* See *e.g.* Moseley's "Principles of Engineering," 1843, pages 149—155.

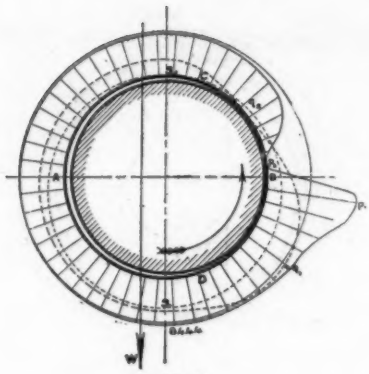


FIG. 3

The distribution of pressure all round the journal—the interspace all being filled with lubricant—is shown diagrammatically in Fig. 3.

When the speed of rotation is slow the pressure is very great at p_1, just before B, the point of nearest approach, is reached, and falls to nothing at p_2 just after it is passed. It then soon rises and maintains a nearly constant value right round from C through A to D, after which it quickly increases to its maximum.

For greater values of the speed of rotation the maximum value of the oil pressure diminishes, and its position (q_1) recedes from the neighbourhood of B; whilst at the same time, the position of the place where the oil pressure is nothing (q_2) advances by an equal amount on the other side of B. The point of nearest approach of journal and brass still remains at B, however; but the journal becomes less eccentric. If the speed were infinitely great the journal would run centrally in the brass, and the position of maximum and minimum fluid pressure would be vertically below and above the centre, viz., at s_1 and s_2, *i.e.*, in the line of the load—see Fig. 3.

The important physical results depicted qualitatively in this figure (3) enables us to fix upon the best position in the circumference of the bearing at which the lubricant ought to be applied.

With reference to the familiar instance of the front bearings of a lathe spindle we have, for the two cases of ordinary and forced lubrication, the following rules:—

Automatic Lubrication.—If the oil is fed in by the ordinary cup and syphon, or by a ring or centrifugal method of supply, it should obviously be made to flow on to the journal at the place where the pressure is least; *i.e.*, at p_2, q_2, or s_2, Fig. 3. It will not enter at p_1 or q_1 unless it is under a greater head than that of the oil film at these points.

The oil ways should therefore be fed from a point situated in the top rear quadrant of the bearing when the journal is loaded by gravity only, and the point should be further back the slower the speed. This applies, then, especially to large lathes.

If the loading of the journal is principally due to cutting force acting upwards upon it, the feed should obviously be placed in the bottom front quadrant, and nearer the front the slower the speed of rotation. This meets the case of the smaller sized lathes.

The compromise ordinarily effected to enable the lubricant to enter, whatever may be the direction of the loading, is the simple one of fitting the oil cup on the top of the bearing. This seems almost the only thing to do in the case of automatic lubrication; but it is the correct position only when the resultant force upon the journal, due to gravity and cutting force, &c., acts nearly horizontally and from front to rear.

Forced Lubrication. — When the lubricant is supplied by mechanical means at a fixed rate and at any required pressure it must be fed in at the points (p_1, q_1) of greatest oil pressure in the bearing. For engine bearings fitted with what is called forced lubrication it is usually fed in at the points p_2, q_2, and s_2. The advantages of the system are not then fully realised.

For large lathes, where gravity is more important, the region of greatest pressure lies in the rear bottom quadrant.

For small lathes, on the other hand, in which the force on the spindle acts upwards, owing to the cutting force being relatively greater, the maximum oil pressures occur in the front top quadrant.

To meet all contingencies it would appear, on the whole, best, in the case of forced lubrication, either to force the oil in at the back of the bearing, well below the centre; or, preferably, to fit three alternative branches from the oil pressure supply pipe to the back, top, and front, any one of which may be turned on at will to suit the conditions of working.

Frictional Resistance Due to Viscosity.—In describing the phenomena occurring when a journal rotates in a bearing, we have, so far, not alluded to the nature or magnitude of the frictional resistance experienced when there is an abundant supply of lubricant completely separating the former from the latter, and preventing any metal-to-metal contact.

It is frequently stated that "there is no friction without abrasion," or, in other words, that unless two metals rub against each other, there can be no resistance due to relative motion. This, however, is not the case. When a film of lubricant is interposed between two metallic surfaces there is a resistance to relative motion of these surfaces due to the shearing or transverse distortion of the oil film.

In the case of the shearing of a solid, we know that Hooke's law, *ut tensio sic vis*, applies; so that if q, Fig. 4, be the shear stress, and $\frac{s}{y}$ the shear strain, we write $q = G\frac{s}{y}$, where G is the modulus of transverse elasticity. But if the surfaces AA, BB are separated from one another by a liquid of thickness y, and AA moves with speed v relatively to BB, the resistance no longer depends upon the mere magnitude of the angle θ, but upon the rate of its increase with time. If a is the area of either liquid surface, the force required to maintain the steady speed v is

$$F = qa = \frac{kav}{y} \qquad (1)$$

where k is called the coefficient of viscosity of the liquid. [This coefficient is clearly that force which will move a unit area of surface with unit speed relatively to another surface from which it is separated by unit thickness of the liquid in question.]

A film of oil of *uniform thickness* y, all round a journal of diameter d and length l, and adhering to it and to the bearing surrounding it, will thus oppose a resistance to the rotation of the former with surface speed v of the amount

$$F = \frac{k\pi dlv}{y} \qquad (1)$$

In such a case the *friction would not depend on the load*, which does not appear at all in the expression; and it will be readily admitted that the force required to distort the oil film cannot depend on the fluid pressure to which it is, at the moment, subjected. The friction is governed only by the area of viscous fluid to be sheared, and the viscosity of the oil—*i.e.*, the kind of oil and its temperature (with which the viscosity greatly alters)—and it also gets greater the smaller (y) the thickness of the film; so that if the journal is a close fit within its bush the resistance to motion will be greater than if the fit is an easy one.

There are, unfortunately, very few cases in engineering practice where a journal rotates with a uniform thickness of oil

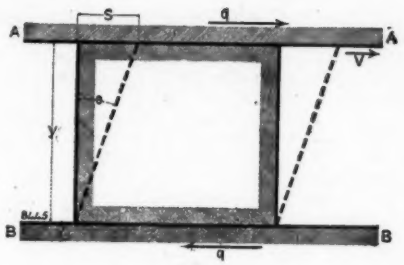


FIG. 4.

around it. It is only when the speed is very great indeed that this can happen—as with steam turbines and mill spindles. At moderate and low speeds we know, as above described, that the shaft moves to one side by an amount which depends on the speed and the load, the eccentricity for any given load becoming less the greater the speed. We have just seen that the frictional resistance depends on the thickness of the oil film, but it is known from the researches of Osborne, Reynolds, and Sommerfeld that the diminution of frictional resistance, due to the thickening of the film on one side of the shaft, is more than made up for by its increase due to the thinning on the other. On the whole, therefore, the friction gets greater when the journal becomes more eccentric.

Starting therefore with a bearing running slowly, in which the lubricant has just formed a complete film all round the shaft, it will have its maximum amount of eccentricity, and the frictional resistance will on this account be large.

As the speed is increased, the eccentricity diminishes. The friction should, according to the simple law of oil shearing given above, increase with the speed; but it should diminish on the other hand with the eccentricity. We find, in fact, that at first it diminishes more than it increases, and in this way (the coefficient of friction) attains a minimum value which depends on the circumstances. With further increase of speed the diminution of friction due to the lessening eccentricity becomes insignificant, and for a certain interval the simple law of friction is followed, whereby the friction increases proportionally to the velocity of rubbing.

For speeds greater than about from 20 to 80 ft. per min. (depending on the kind of bearing) the simple law of fluid friction is interfered with for another reason.

On account of the high speed, the temperature *in the oil film itself* rises above that

of the bearing (even when the latter is artificially maintained as constant) and its viscosity becomes reduced. The frictional resistance then increases less rapidly than in exact proportion to the speed.

The faster the journal runs, the more the temperature of the oil film rises above that of the bearing, and the thinner or less viscous becomes the oil. For speeds from 50 to 90 up to about 450 ft. per min., the coefficient of friction is proportional to the square root of the speed of rubbing. For speeds between 450 and 800 ft. per min., the friction increases more slowly still, and, according to Thurston, μ varies as $\sqrt[5]{v}$. For speeds of the order of 3,600 ft. per min. and upwards, the influence of speed disappears altogether, and the conclusion arrived at by Lasche (*v.* "Traction and Transmission," vol. VI., p. 43) is that, for the bearings of high-speed generators driven by steam turbines, whose rubbing speeds are nearly a mile a minute, the coefficient of friction is the same whatever be the speed.

Examples of curves of frictional resistance obtained by experiment for low and moderate speeds are shown in Fig. 5. They are principally those found by Stribeck for experiments with a "Sellers" bearing (*v. Z. d. V. d.* Ing., September 6, 1902) having double-ring lubrication, the material being gun-metal.

The two thick dotted curves are taken from Heimann's report on experiments by the method of Dettmar (*v. Z. d. V. d.* Ing., Bd. 49, p. 1161). They refer to a *solid bush* of gun-metal, with an unbroken film of lubricant all round, which is very different in its method of action from the "Sellers" or half brass journal experimented on by Stribeck. This accounts for the difference in the shape of the two sets of curves.

THE COEFFICIENT OF FRICTION OF LUBRICATION.

The curves give the "coefficient of friction" on a base of speed of rubbing in feet per minute.

The term "coefficient of friction" denotes the ratio of the total resistance in the bearing due to the shearing of the lubricant, to the load on the journal; and although it has no physical meaning, it supplies a convenient and conventional method of discussing the results.

If F denote the resistance, and P the load, we have

$$\mu = \frac{F}{P} = \frac{k\pi dlv}{Py} \qquad (2)$$

and if $\frac{P}{dl}$ be, as usual, denoted by p, and called the *bearing pressure*, or load per unit of projected bearing area, we see that

$$\mu = \frac{k\pi}{y}\,\frac{v}{p} = c\,\frac{v}{p} \qquad (3$$

or the *coefficient* of friction would vary as the speed and inversely as the bearing pressure *if the oil film were of uniform thickness all round, and the temperature of the lubricant were constant.*

Referring to the dotted curves—thick lines—we observe that μ is not proportional to the speed in the actual experiments even when the temperature of the *bearing* is kept constant throughout.

We see that it increases less rapidly than the velocity of rubbing when the speed is greater than about 20 to 80 ft. per min. This is due to the fact already mentioned that the difference between the actual temperature of the oil film and that of the bearing gets greater as the speed increases, so that although the *bearing* temperature may remain the same throughout a series of experiments, that of the film of lubricant itself, upon which the value of k—the coefficient of viscosity—depends, does not. Thus μ falls away from the simple linear law the more the greater rubbing speed becomes.

These—as also Beauchamp Tower's experiments—show that the "coefficient of friction" in a lubricated bearing follows the law $\mu = \frac{c\sqrt{v}}{p}$ (instead of $\eta = cv/p$, as given above).

Upon further examination of the experimental results plotted as curves upon Figs. 5 and 6, we observe that for speeds below about 20 ft. per min. the coefficient of friction diminishes for a little in exact proportion to the speed, but that the effect of the relatively great eccentricity of the journal in the bush soon begins to have an important influence in increasing the friction; so that after a while the curves of μ take reverse turns, and the coefficient attains a minimum value as described above.

As to the positions of the minimum points, we see that the coefficient of friction takes its least value for speeds which depend upon the bearing pressure; those speeds being greater the greater the bearing pressures—Fig. 5.

After the minimum points are passed the curves begin to rise more or less rapidly as the speed continues to fall. This is due to the oil film being squeezed out of the bearing; and we shall find it necessary to attach great importance in the sequel to this so-called "minimum point," as bearings must

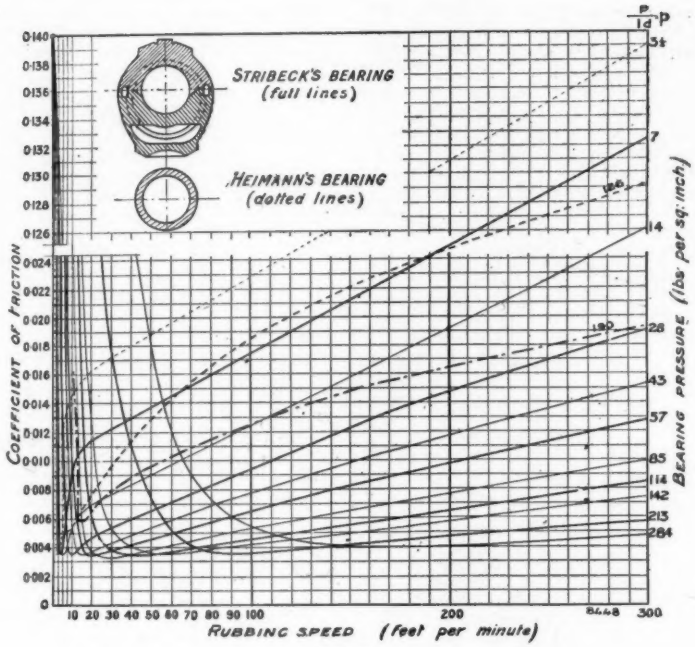


FIG. 5.

be designed so as to avoid such speeds and pressures as correspond to them.

In Fig. 6, reproduced from Heimann's article (*loc. cit.*), we observe the effect on the coefficient of friction and on the positions of its minimum points, of an increase of the temperature of the bearing. The higher the temperatures at which the bearing runs the smaller the coefficient of friction, and the greater are the speeds at which the minimum values of that coefficient are attained.

In conclusion, we observe that the curves all rise very rapidly when the speed is very slow and the oil has all been squeezed out of the bearing; and that they tend to converge upon the constant value 0·15, the coefficient of friction for greasy metals sliding upon each other, long ago determined by Morin. It is only then that μ remains constant, and that we encounter a frictional resistance and loss of work proportional to the load on the bearing and of the amount already calculated.

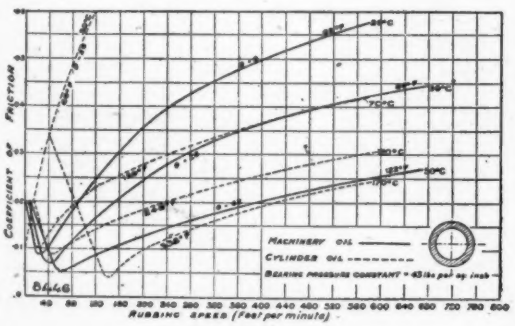


FIG. 6.

Formula for Coefficient of Friction.—Reverting to the theoretical law of fluid friction mentioned above, viz.:—

$$\mu = \frac{c\,k}{y}\,\frac{v^n}{p}$$

we find that experiments show that n has values diminishing from $\frac{1}{2}$ to 0 as the speeds increase from 100 to 3,600 ft. per min.

Clearly, the variation should be

made in the value of k, the viscosity coefficient, and not in that of v; for the law of shearing resistance is equally kv/y at high as at low temperatures.

If we could calculate the excess of mean temperature of the oil film over that of the metal walls between which it is flowing, then knowing how k depends upon that (mean) temperature, we could predict the proper form of the expression for any given case.

The author has found a simple expression which gives values of k with fair correctness between the temperatures 70° and 160° F.; the more correct expression of Osborne Reynolds—$k = 0{\cdot}000047\epsilon^{-0{\cdot}0281t}$.

The formula is

$$k = \frac{B}{(t-60°)}, \text{ or } k = \frac{B}{\theta}, \text{ where } B \text{ has the value } \frac{1}{500}.$$

Thus we write $$k = \frac{1}{500\theta} \qquad (4)$$

A roughly accurate expression for the coefficient of friction for machinery oil as deduced from these experiments will therefore be (for speeds over 20 ft. per min.):

$$\mu = \frac{c\sqrt{v}}{\theta p} \qquad (5)$$

$$\mu = \frac{500\sqrt{v}}{500\theta p} = \frac{1{\cdot}8\sqrt{v}}{\theta p} \qquad (6)$$

Here v = surface speed in feet per minute.

p = bearing pressure in pounds per square inch.

and θ = excess of oil temperature above 60° F.

This may be written in the form:

$$M = \mu p = \frac{1{\cdot}8\sqrt{v}}{\theta} \qquad (7)$$

where M may be called the specific friction. It is the frictional resistance per square inch of projected bearing surface. Its values are given in Fig. 7.

Application of the Above Formula in the Design of Bearings.—In endeavouring to apply the theoretical explanations and experimentally derived formulæ

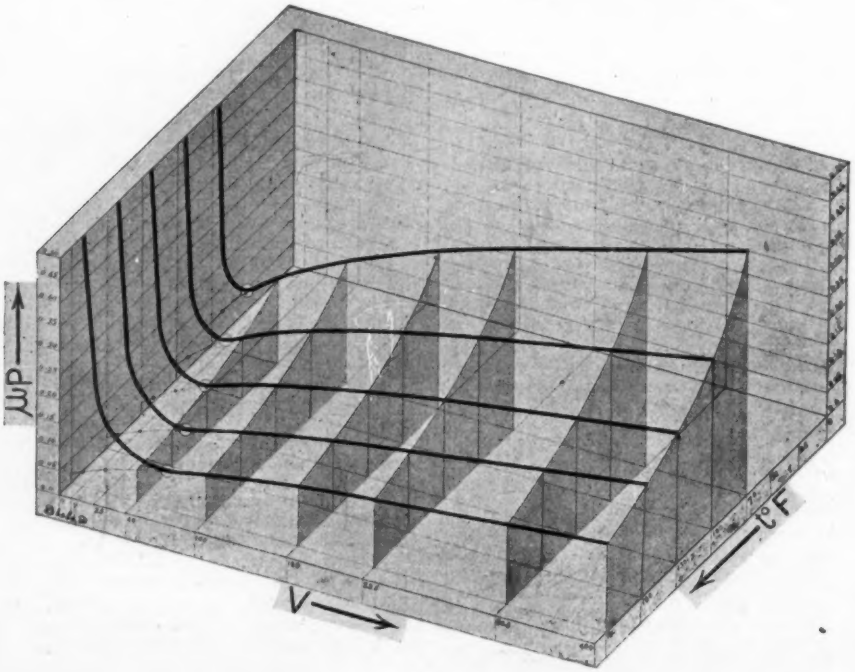


FIG. 7.

discussed above to the design of a bearing, what we want to know is:—What is the proper proportion of length to diameter under any given conditions as to load, speed, and mode of lubrication; having regard also to the fact that the requirements demanded from the point of view of strength and stiffness must also be met.

We have to consider how much heat is generated by the viscous resistance opposed by the oil to the rotation of the shaft, in what manner this heat is dissipated, to what temperature the bearing will rise in actual running, and what law connects the temperature at which the journal may safely run with the pressure and the speed.

The heat generated is obviously equal to $\frac{\mu P \pi d N}{12J}$ thermal units per minute, if d is the journal diameter in inches, P the load in pounds, μ the coefficient of friction, and N the number of revolutions per minute.

If the heat dissipated by radiation from the surfaces of the housing and shaft be, as usually assumed, proportional to dl, the projected bearing area, and to θ the temperature difference between bearing and external air; then, when the temperature of the bearing becomes steady, we shall have (e being the emissivity coefficient)

$$\frac{\mu P \pi d N}{12J} = edl\theta \qquad (8)$$

In the standard text-books—*e.g.*, Unwin's "Machine Design," vol. i., p. 240—it is usually assumed *that whatever may be the diameter or length of the proposed journal the value of μ will remain constant.* In that case

$$l = \frac{\mu P \pi N}{12Je\theta} = \frac{\mu\pi}{12Je\theta} PN = \frac{PN}{\beta} \qquad (9)$$

which means that the length of the bearing must increase with the load and the revolutions.

As a matter of experimental fact, however, μ is by no means constant. It depends on speed, pressure, and temperature, and, as we have already seen, we may take it to follow the law

$$\mu = \frac{1{\cdot}8\sqrt{v}}{\theta p} \qquad (10)$$

This erroneous assumption of μ a constant, as usually made, leads to merely arbitrary determinations of journal lengths by the use of the constant β. If we consult the above text-book, p. 193, we shall find that this so-called constant (β) varies in value from

30,000 to 1,500,000!

A good deal is thus left to the taste and discrimination of the designer.

The more correct method will be to use the value for the coefficient of friction which has been determined by experiments upon bearings as above described.

If, then, we insert this value in (18), we obtain

since $$v = \frac{\pi d N}{12}$$

$$\mu \frac{cP(\pi dN)^{\frac{3}{2}}}{13^{\frac{3}{2}} p\theta J} = edl\theta$$

With $c = 1{\cdot}8$, $\frac{P}{p} = ld$, and $J = 778$, we get

$$\theta^2 = \frac{(dN)^{\frac{3}{2}}}{3400e} \qquad (11)$$

To determine the value of e, the emissivity coefficient, we may apply this formula to Stribeck's results from his Sellers bearing (see his figure 5 *Z. d. V. d.* Ing., September 6th, 1902). This bearing of diameter 2·76 in. attained—according to that figure—after running for three hours at 760 revs. per min., a final temperature of about 140° F. Therefore

$$\theta = 80° \text{ F.}$$

Hence from

$$e = \frac{(dN)^{\frac{3}{2}}}{7\theta^2}$$

we obtain

$$e = \frac{(2{\cdot}75 \times 760)^{\frac{3}{2}}}{3400 \times 80^2} = 2\tfrac{1}{2}\sigma \text{ B.Th.U.} \qquad (12)$$

dissipated per square inch of projected bearing area per minute per degree difference of temperature F., between the bearing and the outer air.

Thus the formula for θ, the final rise of temperature of a bearing above its surroundings, becomes

$$\theta = \frac{(dN)^{\frac{3}{4}}}{\sqrt{3400 \times 2\tfrac{1}{2}\sigma}} = \frac{(dN)^{\frac{3}{4}}}{\sqrt{15{\cdot}6}}$$

or in round numbers

$$\theta = \frac{(dN)^{\frac{3}{4}}}{4} \qquad (13)$$

Expressed in words, this means tha the steady or finally attained temperature of a bearing of given diameter is higher the greater the $\frac{3}{4}$ power of the revolutions, and is greater for a given speed the larger the $\frac{3}{4}$ power of the diameter. *It is, however, quite independent of the length of the journal.*

We cannot, therefore, hope to lower the terminal temperature by lengthening the bearing. The heat generated increases as fast as the area for dissipating it does; for although by lengthening the journal the bearing pressure is diminished, yet since μ varies inversely as p, the frictional resistance and the heat generated are *pari passu* increased.

We know, however, from experience, that journals must be made long for high speeds, and the above conclusion seems at first sight to conflict not only with the text-books, but also with practice, and so to be paradoxical.

The explanation is as follows: Whilst it is true that the final temperature to which a bearing will rise after a long run under a given load, and with a given lubricant, depends only on the diameter of the spindle and on the speed of revolution, *i.e.*, only on the rubbing velocity, and not at all upon the length of the journal, we have to remember that *if that finally attained temperature be too high the lubricant will be squeezed out unless the bearing pressure is low.*

If, referring to Stribeck's and Heimann's curves—Figs. 5 and 6—we take it that the conditions attending the minimum values of the coefficient of friction are those under which the oil begins to escape from the bearing, and that for any lower speed the bearing will run dry, we may find the connection between rubbing speed and temperature on the one hand, and rubbing speed and pressure on the other, which specifies the condition of safe running with a complete oil film.

According to Heimann's curves (Fig. 6) from experiments in which the temperature of the bearing was varied, whilst the bearing pressure remained the same, it appears that the coefficient of friction attains a minimum for a different value of the surface speed for each different temperature, and that the value of this speed increases proportionately to the temperature, as numerically stated on the Fahrenheit scale. In fact, if v_0 be the value of the speed for the minimum, and t the bearing's temperature, Fahrenheit, we find $v_0 = \frac{1}{3}t$.

From Stribeck's and Heimann's curves (Fig. 5) drawn from experiments in which the bearing pressure was varied, the temperature remaining unaltered, the speed for the minimum coefficient is found again to be proportional to the pressure. For Stribeck's Sellers bearing $v_\circ = \frac{1}{2}p$, and for Heimann's —solid—brush bearing $v_\circ = \frac{1}{14}p$.

Thus $v_\circ$ varies as t when p is constant, and $v_\circ$ varies as p when t is constant; therefore, when both p and t vary, $v_\circ$ will vary as their product; or $v_\circ = Apt$.

The value of A in this expression is found to be different not only as between Stribeck and Heimann, but also as between Heimann's constant temperature and his constant pressure experiments.

For Stribeck's Sellers bearing we get

$$v_\circ = \frac{pt}{35} \text{ (constant temperature).}$$

For Heimann's bush bearing we get

(*a*) For constant temperature experiments

$$v_\circ = \frac{pt}{82}$$

(*b*) For constant temperature experiments

$$v_\circ = \frac{pt}{190 \text{ to } 240}$$

Now, Sommerfeld has deduced mathematically an expression for this very speed for the minimum coefficient of friction, in terms of the bearing pressure, p; the radius of the journal, r; the difference between the radii of bearing and journal, δ; and the coefficient of viscosity, k.

It is of the form

$$v_\circ = K \frac{\delta^2}{r^2} \frac{p}{k} \qquad (14)$$

We also found above that the coefficient of viscosity for machinery oil is, for temperatures between 68° F. and 160° F., well represented by the expression $k = \frac{c}{(t^\circ - 60^\circ)}$ or $k = \frac{c}{\theta^\circ}$ (units = pounds, feet, and deg. F.).

Substituting for this k in (14) we obtain

$$v_\circ = Cp\theta \qquad (15)$$

where C is a constant, *varying as the square of the ratio of the original slackness of fit to the size of the journal.*

We prefer, therefore, to use the formula $v_\circ = Cp\theta$, which has a theoretically sound basis, rather than the form $v_\circ = Apt$, which can be made to agree with the experimental data of Stribeck and Heimann, more especially as the value of A differs so much for the different sets of curves. We ought, no doubt, to expect to find a difference for this constant as between the Sellers type of bearing used by Stribeck and the bush bearing of Heimann, but the large variation of A in the two sets of (pressure and temperature) curves given by Heimann for the same type of bush bearing seem to point to some discrepancy, such as a considerable difference in the original amount of slackness allowed between journal and brass in the two runs.

We shall, therefore, use for our purposes in designing bearings the expression $v_\circ = Cp\theta$, with $C = \frac{1}{40}$ for the value of the constant; and when written in the form

$$\theta_c = \frac{40 v_\circ}{p} \qquad (16)$$

we see that *it gives the critical value* (θ) *of the rise of temperature, above which, under the given conditions as to surface speed* ($v_\circ$ ft. per min.), *and bearing pressure* (p lbs. per sq. in.), *the oil will be in danger of leaving the*

bearing and allowing it to run with metallic contact of the rubbing surfaces.

What we are now proposing then is to fix the proportions of journals by reference to the minimum points of the experimental friction curves already discussed, assuming them to indicate the critical conditions as regards speed, pressure, and temperature of the bearing, below which it is unsafe to run.

We first calculate the terminal rise of temperature of the bearing by the expression $\theta_f = \frac{(dN)^{\frac{3}{4}}}{4}$. We then equate this to the value $\theta_c = \frac{40v}{p}$ of the above critical temperature; and so obtain a relation between the length, the load, the diameter, and the speed of revolution.

We thus have

$$\frac{(dN)^{\frac{3}{4}}}{4} = \frac{40v}{p}$$

Substituting $\frac{\pi dN}{12}$ for v, and $\frac{P}{ld}$ for p, we may write this

$$\frac{(dN)^{\frac{3}{4}}}{4} = \frac{40\pi d^2 Nl}{12P}$$

from which we obtain

$$l = \frac{P}{40d^{\frac{5}{4}}N^{\frac{1}{4}}} \qquad (17)$$

This is the formula proposed for use in the design of journals for speeds of rubbing up to about 450 ft. per min.

It has been found to agree well with practice in all the different examples on which it has been tested.

In those cases in which it does not agree, it is to be surmised that the practitioner has been misled by adherence to the erroneous theory alluded to above.

As an example of the use of the formula we may take the case of self-oiling bearings for line shafting.

For ring-oiled bearings or other cases in which an abundant supply of lubricant can always be maintained between journal and brass we proceed in the following manner:—

The critical temperature of the bearing expressed as an excess above 60° F. is:—$\theta_c = \frac{40\,v_o}{p}$; v_o being the speed (ft./min.) at which metallic contact is in danger of occurring under the given bearing pressure p (lb/sq. in.).

The finally attained temperature of the bearing of diameter d (inches) [after running. *i.e.*, for several hours] at the speed of revolution N (revs./min.) is (also in excess of 60° F.)

$$\theta_f = (d\,N)^{\frac{3}{4}}/4.$$

For cool running, without wear, we must therefore have θ_f, less than, or at most equal to, θ_c, *i.e.*, $\frac{(dN)^{\frac{3}{4}}}{4} < \frac{40\,v_o}{P}$

Now if l is the (unknown) length of the bearing and P its given load, we have $p = \frac{P}{ld}$. Also, if the final temperature attained is allowed to be just over the critical temperature corresponding to the given speed and load: then $v_o = \frac{\pi\,d\,N}{12}$.

So that we have—

$$\frac{(d\,N)^{\frac{3}{4}}}{4} = \frac{40\,\pi\,d^2\,N\,l}{12\,P}$$

or

$$l = \frac{P}{40\,N^{\frac{1}{4}}\,d^{\frac{5}{4}}}$$

The values of $p = \frac{P}{ld} = 40\,(d\,N)^{\frac{1}{4}}$, for the various cases usually occurring in practice (that is for ordinary values of d and N) have been calculated. They are shown as curves in the annexed Fig. 8.

Thus if we have a shaft 2 in. diameter running at 100 revs. per min., the bearing pressure which must not be exceeded if a complete film is always to be maintained is by the diagram 150 lb. per sq. in. Hence, if the load (P) were 600 lb., the length of the journal would be

$$l = \frac{P}{150\,d} = \frac{600}{150\,d} = \frac{4}{d} = 2 \text{ in.}$$

If the load were 1,200 lb., the journal would have to be 4 in. long, and so on.

With the same diameter of shaft, if the

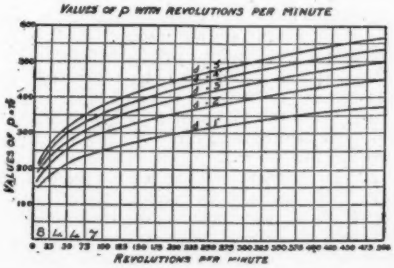


FIG. 8.

speed were only 25 revs., the bearing pressure allowed would be reduced to about 100 lbs.; and the length would be

$$l = \frac{P}{100\,d} = \frac{600}{100\,d} = \frac{6}{d} = 3 \text{ in. for a}$$

600 lb. load.

If, on the other hand, the speed were 500 revs./min., the bearing pressure might be as high as 225 lb., and the length need only be $l = \frac{600}{225\,d} = 1\frac{3}{8}$ in.

In other words, the allowable bearing pressure $p = \frac{P}{ld}$ varies between 100 lb. and 225 lb. per sq. in. according to the expression, for the different speeds and diameters above indicated.

It will be noticed that, contrary to the view usually accepted, the length must be greater the *slower* the speed.

This is clearly correct; for the slower the speed the greater difficulty has the journal in dragging in its supply of oil to meet the required demand in opposition to the bearing pressure which is squeezing it out.

The lower must that bearing pressure accordingly be; *i.e.*, the greater l for a given d, in order to enable the journal to maintain its oil film unbroken.

Journals for Heavy Loads at Low Speeds.—Another set of conditions which are frequently met and have to be dealt with in practice are those in which a journal has to run under a heavy load at a very slow speed.

What we have now to guard against is the entire collapse or tearing asunder of the film of lubricant, owing to the slow speed at which the bearing is being worked. Stribeck's and Heimann's curves of speed and pressure, at constant temperature, show that, after the minimum points are passed, as the speed still further diminishes, the coefficient of friction begins to rise very rapidly, and that, whatever the load may be, all the curves converge upon the value 0·15, the coefficient of "dry" friction for greasy metals, determined by Morin. The rate of rise of the friction curve depends on the amount of bearing pressure, being much more rapid, at all events for a "Sellers" bearing, *vide* Fig. 7, for low than for high bearing pressures.

A low pressure is accompanied by a low speed for the "minimum point," and when once the tearing of the oil film begins the journal is unable to bring up a fresh supply, owing to its small surface speed. High bearing pressures have their minimum friction points at high speeds, and the journal brings up considerable quantities of oil, even when the speed has become low enough to break the film, so that the resulting friction is probably partly due to viscous resistance and partly to metallic contact.

The values of the speeds for the minimum points of the coefficient of friction curves, Figs. 5 and 6, as they depend on the bearing pressures which we used before, will now again serve as indicating the dangerous conditions to be avoided if the oil film is to remain unbroken.

The "Sellers" bearing gave the relation $v_o = \frac{1}{2}p$, and the bush bearing $v_o = \frac{1}{16}p$ for these points. If, therefore, the surface speed of the journal be v feet per minute, the bearing pressure may not exceed $2v$ lbs. sq. in. for a bearing in halves, and $16v$ for a solid or bush bearing, if metal-to-metal contact of journal and bearing is to be avoided.

A very commonly occurring case is that of an ordinary lathe spindle when taking its deepest cut or carrying its heaviest load at its slowest velocity of rotation.

It may fairly be assumed that every lathe will at times be called upon to take a finishing cut at a speed of 18 ft. per min. upon a heavy job of face-plate diameter of the greatest length the lathe can take in, and of which one-third the weight will be taken by the front journal. We obtain, therefore, the following value of load and speed (h = height of centres):—

The weight of the job assumed, $2h$ in diameter and $6h$ long, is

$$\frac{\pi}{4}(2h)^2 \times 6h \times 0{\cdot}3 \text{ lb.} = 5{\cdot}66h^3 \text{ lb.}$$

One-third of this will be $2h^3$ (and allowing for the weight of face-plate, &c.), or $W = 2h^3$.

If the bearing be taken of diameter $\frac{h}{3}$ the rubbing speed is $\frac{18 \times h}{3 \times 2h} = 3$ ft. per min.; and, according to the above table, the safe load is therefore from 6 lb. to 48 lb. per sq. in. of projected bearing area. But the actual bearing pressure will be, if we assume the usual value $\frac{h}{2}$ for the length of the journal

$$p = \frac{2h^3}{\frac{h}{2} \times \frac{h}{3}} = \frac{12h^3}{h^2} = 12h\text{; } i.e. \text{ 120 lb./sq. in.}$$

for a 10 in., and 600 lb./sq. in. for a 50 in. lathe.

We see, therefore, that it is impossible to give the large dimensions to the front bearing that would be necessary to prevent the oil film from being broken at such slow speeds; and, *as a matter of fact, lathe spindles turning at the slow speeds used for heavy cuts inevitably run metal-to-metal with their brasses, giving rise to the high frictional resistance corresponding to the coefficient of friction of* 0·15 *for greasy metals.*

The work thus spent and wasted on friction and wear may, as worked out above, amount from 2 per cent. to 10 per cent. of the total useful work expended on cutting. From $\frac{1}{4}$ to 9 (according to size) h.p. is, therefore, wasted on the friction *of the front journal alone* when the lathe is running at these slow rates with a heavy job between centres.

Even if the job be light, and the thrust on the front journal that due to the standard cut only, it can be shown that $2\frac{1}{2}$ per cent. of the useful work is spent on friction on any size of lathe when the speeds are so low as to squeeze out the oil film.

We are here face to face with a very serious loss of power, and a correspondingly large amount of wear of the spindle and brasses in the front bearing not at all due to high speeds of rotation of the spindle; and it is owing to this that the elaborate arrangements for adjustment of the spindle in a lathe headstock have to be provided.

It is impossible to give enough area in the front bearing of a lathe headstock to prevent metallic contact of journal and brass at the slower speeds, if dependence is placed upon the lubricant being carried in by the ordinary action of the shaft's rotation, the supply being automatic.

By using a force pump, however, and injecting a stream of moderately heavy oil into the bearing *at the place where the pressure is greatest*, it is possible to raise the journal off the brass even when at rest, and to keep it floating with a film of oil interposed between itself and the bearing when in motion, be that motion as slow and the load as high as it may.

If metal-to-metal contact can in this way be prevented at slow, and by the ordinary methods at high, speeds, there seems to be a possibility that *wear may be entirely eliminated.*

If this be so, it follows *that adjustments for wear are unnecessary*, and instead of the elaborate and expensive designs of front and back bearings which are now used, we may expect that a simple and solid bush of ample thickness, and of a length not greater than $2\sqrt{h}$, as indicated above, will meet every requirement.

Such a solid bush, of hard bronze round the steel spindle, has a great deal to recommend it from the point of view of accuracy of fit, solidity, and stiffness, as compared with the intricate methods of adjustment which are now common.

Powers Required to Drive Machine Tools.

	H.P.
Drills.	
Sensitive drills	$\frac{1}{4}$
12 in. to 20 in. upright drills	1
20 in. to 24 in. „ „	$1\frac{1}{2}$
26 in. to 30 in. „ „	$2\frac{1}{2}$
30 in. to 40 in. „ „	$3\frac{1}{2}$
36 in. to 40 in. radial drills	$1\frac{1}{2}$
4 ft. to 5 ft. „ „	2
6 ft. to 8 ft. „ „ ...	3 to 5
Lathes.	
Speed lathes	1
22 in. and 24 in. engine lathes	2
26 in. and 30 in. „ „	$2\frac{1}{2}$
36 in. and 42 in. „ „	$3\frac{1}{2}$
48 in. and 54 in. „ „	5
60 in. engine lathes	6
72 in. „ „	$7\frac{1}{2}$
84 in. „ „	10
Heavy-duty Lathes.	
24 in. to 30 in. lathes	15
36 in. to 48 in. „	20
54 in. to 72 in. „	25
Boring Mills.	
37 in. boring mill	4
51 in. „ „	5
5 ft. „ „	6
6 ft. „ „	$7\frac{1}{2}$
7 ft. to 9 ft. boring mills	10
10 ft. boring mill	12
12 ft. to 16 ft. boring mills	15
16 ft. to 25 ft. „ „	18
Planers.	
20 × 20 in. × 6 ft. single-head planer ...	$3\frac{1}{2}$
30 × 30 in. × 8 ft. „ „ ...	5
42 × 42 in. × 10 ft. „ „ ...	$7\frac{1}{2}$
60 × 60 in. × 12 ft. double-head planer...	10
72 × 72 in. × 14 ft. „ „ ...	15
84 × 84 in. × 18 ft. „ „ ...	20
9 × 10 × 24 ft. „ „ ...	30
12 × 12 × 24 ft. „ „ ...	40
Shapers (Single-head Machines).	
16 in. stroke	2
24 in. „	3
30 in. „	5

American Machinist.

The Predetermination of Train-Resistance.

At a recent meeting of the Institution of Civil Engineers, a paper was read on this subject by Prof. Carus-Wilson, M.A., A.M.Inst.C.E. The author first considered the form of the resistance-equation and different elements of train-resistance, namely, journal-friction, rolling-friction, track-resistance, flange-action, and air-resistance. Each element of resistance was given in terms of the known variables, and existing experimental results bearing on the question were reviewed. The conclusion is arrived at that the component parts of train-resistance may be divided into three groups, distinguished by their relation to the speed. The resistances are (1) those independent of the speed, and include journal-friction, rolling-friction, and track-resistance; (2) the resistance caused by flange-action, which varies as the first power of the speed; (3) which includes all forms of air-resistance, which vary as the square of the speed. The resistance-equation is thus shown to be of the form $R = A + Bv + Cv^2$.

The second section was devoted to the determination of the constants in the resistance-equation. The different methods of making train-resistance tests, and the errors to which they are liable, were considered. For the purpose of determining the constants the author selected the tests made by Mr. Barbier on the Northern Railway of France, as being the most complete and reliable tests of which full records have been kept. These tests were made on two classes of rolling stock, namely, four-wheel and bogie coaches, and a comparison of the results obtained in the two cases, as represented by curves which were reproduced, furnishes a means of arriving at the constants in the resistance-equation. These constants depend upon the type of rolling stock under test, and formulas were deduced by which the constants for any given type of rolling stock may be obtained.

In the third section the resistance-formulas were applied to a number of different cases in order to ascertain how far they afford a correct predetermination of the resistance of trains made up of rolling stock entirely different from that tested on the Northern Railway of France. For this purpose a number of the most reliable tests available were selected, the resistance computed by the aid of the formulas, and the resistance-curve then obtained and compared with the results of each test. The tests considered were the following:—(1) Tests of bogie-coaches on the Lancashire and Yorkshire Railway. These coaches differ materially from those tested by Mr. Barbier. The curve obtained by the application of the formulas shows a close agreement with the test results, the mean difference at eight selected speeds from 10 to 80 miles per hour being 3 per cent. (2) Tests of four-wheel goods-wagons on the London and North-Western Railway. Here the calculated resistance is 5 per cent. below that obtained by test. (3) Tests on eight-wheel bogie goods-wagons on the New York, Ontario and Western Railway. The calculated value is 8½ per cent. less than the observed value. (4) Tests of eight-wheel electric motor-coaches made by the St. Louis Electric Railway Test Commission. The resistance obtained from the formulas shows a close agreement with that obtained in the test. (5) Tests of twelve-wheel high-speed bogie-coaches at Zossen. The calculated resistance differs from the test value by a constant amount of 100 pounds, being a difference of 7½ per cent. at 60 miles per hour.

In the fourth section the following practical questions were discussed in the light of the conclusions arrived at:—

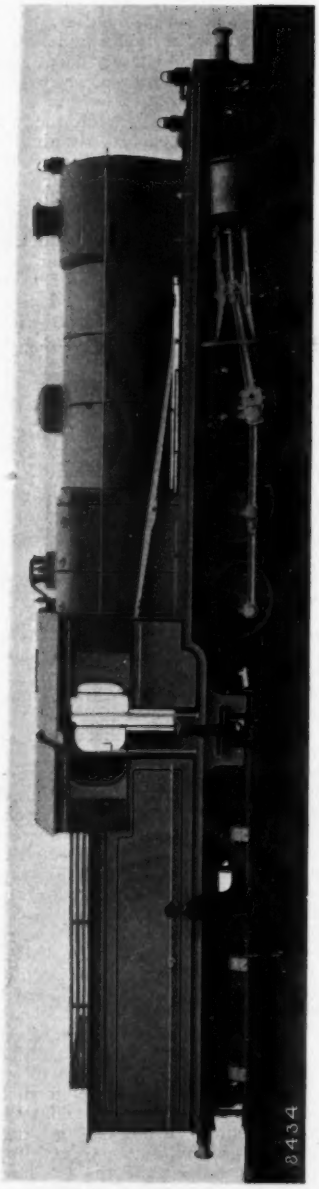
Journal-friction in its relation to train-resistance and its possible reduction by roller-bearings. The real value of roller-bearings in railway traction was shown to lie in the reduction of running-resistance and consequent saving of energy, and not in the reduction of starting-effort. The results of tests with roller-bearings on the Eastern Bengal State Railway were given, the saving

actually obtained being 1 per cent. greater than that calculated by the use of the resistance-formulas. *The influence of the truck on the resistance of bogie-coaches.*—The resistance of a coach was shown to depend largely upon the wheel-base of the truck, and the relation of the weight of the bogie-trucks to that of the whole coach. *The effect of electrical driving on the resistance of bogie-coaches.*—The weight of the motors and the extra weight of the motor-trucks in electrically-driven coaches increases the flange action and the total resistance of such coaches. The resistance of electrical motor-coaches is in some cases as much as 54 per cent. greater than that of trailing coaches running at the same speed under similar conditions. *The reduction of the resistance of goods-wagons by the use of bogies.*—The influence of the bogie on train-resistance is shown to be greatest in the case of goods-wagons. *The relation between the tractive efforts required to haul loaded and empty bogie goods-wagons.*—Since flange-action depends upon the ratio of the weight of the bogie to that of the whole wagon, it must follow that the resistance per ton of a loaded bogie-wagon must be less than that of the same wagon empty. This is a matter of general experience, and can only be explained on the above hypothesis. The results of tests were given in which a train of bogie-wagons was hauled over a considerable distance backwards and forwards, first loaded and then empty. The ratio of the mean drawbar-pull in the two cases was 0·56. When the resistances are calculated by the formulas, the ratio is found to be 0·62. *The incidence of train-resistance on flange- and rail-wear.*—The energy expended in overcoming flange-resistance is represented by the wear of tyres and rails. Tables were given to show how much greater this wearing action is in some cases than in others. *The reduction of flange-action by mechanical contrivance.*—It was shown that by giving the bogie a lead, as is done in Timmis's bogie-lead, the flange-action of the bogie can be reduced, and that the saving depends upon the ratio of the bogie wheel-base to the distance between the bogie centres, and also upon the ratio of the bogie weight to the total weight. *The effect of side play on train-resistance and its possible limitation.*—The amount of play between the flanges and the rails is an important factor in train-resistance. The want of uniformity in current railway practice in this matter was illustrated by a table giving the amount of side play adopted on thirteen different railways in Gt. Britain, in the United States, and on the Continent. The increased resistance and wear occasioned by large flange-play suggests the importance of a reduction of the play to a standard $\frac{3}{8}$ in. as on the London and South-Western and other railways. *The relative importance of air-resistance.*—The resistance of the air with a train of bogie-coaches, running at 60 miles per hour, amounts to about one-half of the total tractive effort required to haul the train. The experiments conducted by the St. Louis Electric Railway Test Commission show that a large reduction can be made in the front and rear air-resistance by shaping the ends, and that by this means a saving can be effected of 10 per cent. of the total tractive effort with a long passenger-train, and 30 per cent. with a single coach.

2-8-0 Type Goods Engine for the Indian N.W.R.

By the courtesy of the builders, the Vulcan Foundry, Ltd., of Newton-le-Willows, we are able to illustrate one of the most powerful goods engines hitherto constructed in this country for service abroad. It is one of an order of forty at present under construction for the North-Western State Railway (5 ft. 6 in. gauge), the design being practically that recommended by the Locomotive Section of the Engineering Standards Committee.

As will be seen, the consolidation, or 2-8-0 type has been adopted with outside cylinders of 21 in. diameter by 26 in. stroke, driving on to the second pair of coupled wheels. Steam distribution is effected by valve gear of the "Stephenson" link type actuating balanced valves of the "Richardson" design. Ample steam supply is provided by a large boiler 12 ft. 6 in. in length by 5 ft. 6 in. diameter, fitted with a "Belpaire" fire-box, 250 tubes, and an extended smoke-box. Four "Ramsbottom" safety valves will be noted set to blow off at the working pressure of 180 lbs. per sq. in. The two-wheeled pony truck is of the swinging bolster type, and is compensated to the spring of the leading coupled wheel. It is capable of a lateral movement $2\frac{3}{8}$ in. in each direction. The radial arm is fixed to the axle-box casting, and is pivoted to a frame stretcher adjacent to the cylinders. Swing links connect the springs, which are placed transversely to the length of the



2-8-2 GOODS LOCOMOTIVE FOR THE INDIAN N.W. STATE RAILWAY.

engine to the top of the axle-box. The following are the leading particulars:—

CYLINDERS.

Diameter	21 in.
Stroke	26 in.
Valve	Richardson's

BOILER.

Diameter (inside)	5 ft. 6 in.
Length	12 ft. 6 in.
Thickness of plates ...	$\frac{5}{8}$ in.
Working pressure	180 lbs.

FIREBOX.

Material	Copper
Length (inside at top) ...	7 ft. $6\frac{7}{16}$ in.
Width	4 ft. $10\frac{3}{4}$ in.
Depth, front	6 ft. 7 in.
„ back	5 ft. 11 in.
Thickness of plates ...	$\frac{9}{16}$ in.
„ „ tube ...	1 in.

TUBES.

Number	250
Diameter (outside) ...	$2\frac{1}{4}$ in.
Length (between tube plates)	13 ft.

HEATING SURFACE.

Fire box	173 sq. ft.
Tubes	1,914 sq. ft.
Total	2,087 sq. ft.
Grate area	32 sq. ft.

DRIVING WHEELS.

Diameter on tread	4 ft. $8\frac{1}{2}$ in.
„ of centre ...	4 ft. $2\frac{1}{2}$ in.
Journals	8 in. by 9 in.

PONY TRUCK WHEELS.

Diameter on tread	3 ft. 7 in.
Journals	$6\frac{1}{4}$ in. by 9 in.

WHEEL BASE.

Rigid	16 ft.
Total, engine	25 ft.
Total, engine and tender ...	50 ft. $4\frac{1}{2}$ in.

FITTINGS.

Injectors: Gresham & Craven's No. 10 self-acting.
Sight feed lubricator: Wakefield's double feed.
Metallic packing: United States.

BRAKE.

Engine and tender: Automatic vacuum.

WEIGHT.

On drivers	$63\frac{1}{4}$ tons
On pony truck	8 tons
Total, engine	$71\frac{1}{4}$ tons
Total, engine and tender ...	118 tons

TENDER.

Diameter of wheels ...	3 ft. 7 in.
Journals	6 in. by 11 in.
Tank capacity	4,000 galls.
Fuel capacity	7½ tons of coal
Tender, loaded	46¾ tons.

Tractive force or $\frac{d^2 hp}{D}$ = 32,875 lbs. at 90 per cent. boiler pressure.

4-6-0 Type, Four-Cylinder Passenger Engine, London and South-Western Railway.

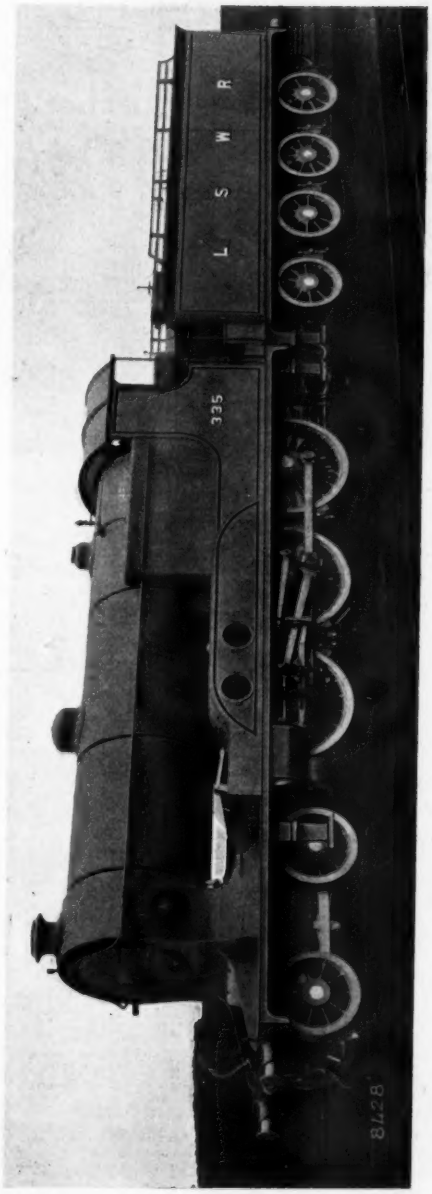
It is a little over two years ago since a series of four-cylinder simple expansion, six coupled type passenger engines were put into service on the London and South-Western Railway.

A new series is about to be introduced by Mr. Dugald Drummond, closely following the lines of the 1905 type, in that the wheel arrangement, boiler, grate area and heating surface dimensions are identical, and that the new engines are fitted with a water-tube firebox, spark arrester, and feed heating apparatus. The three last mentioned features, in fact, have now become standard practice on the South-Western engines, and have been described and illustrated in these columns on their first introduction. The new 4-6-0 four-cylinder type differ from their predecessors in cylinder diameter, which is ½ in. larger, and in piston stroke, which is 2 in. longer. Further the slide valve of the outside cylinders are placed on top in this instance, but are operated by the same type of gear, viz., the Walschaert.

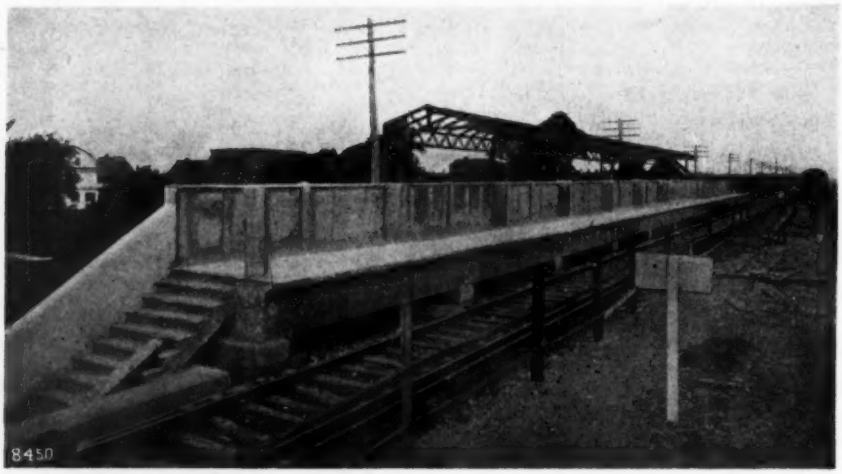
The following are the leading dimensions:—

Cylinders (four), 16½ in. dia. × 26 in. stroke.
Wheels, 6 ft. 0 in. dia., Bogie wheels, 3 ft. 7 in. dia.
Heating surface:—

	Sq. ft.	
340 boiler tubes ...	2,210,	flue tubes
112 firebox „ ...	357,	water „
Firebox ...	160	
Total	2,727	



4-6-0 TYPE FOUR CYLINDER SIMPLE EXPANSION EXPRESS ENGINE, LONDON AND SOUTH-WESTERN RAILWAY.



REINFORCED CONCRETE PLATFORM AND FENCE, BRIGHTON BEACH LINE, BROOKLYN, N.Y.

Grate area, 31·5 sq. ft.
Working pressure of boiler, 175 lbs. per sq. in.
Capacity of tender, 4000 galls.
Coal carried, 4 tons, bogie wheels on tender, 3 ft. 7 in. dia.
Heating surface of tubes in tender well, 382 sq. ft.
Tractive force on rails, 3c,968 lbs.
Total length over buffer (engine and tender), 63 ft. 0¼ in.

Reinforced Concrete for Station Platforms.

A form of construction for platforms and platform fences of exceeding neat appearance has been adopted on the Brighton Beach Line of the Brooklyn Rapid Transit Co., N.Y., and is shown in the accompanying illustration, for which, with the undermentioned particulars, we are indebted to the *Engineering Record*.

The platforms are of reinforced concrete slabs carried by beams and girders of the same material, and are covered with a granolithic finish. The fences referred to are the guard railings on the outside and ends of the platforms.

They run the whole length of the latter, and consist of cement plaster reinforced by a metal lath of No. 28 gauge, having a cross section of 0·18 sq. in. per ft. of width and weighing 67 lbs. per 100 sq. ft.

The lath is 1 in. high, the minimum plaster thickness covering the metal on each side being ½ in.

The lath is carried in continuous sheets through the whole length of the fence, and is not broken at the posts. The latter, which are on 10 ft. centres, are reinforced with four ½ in. rods set deep into the concrete platform. The post is formed by two short pieces of lath bent in the shape of channels and placed round the reinforcing rods, one channel on each side of the continuous sheet, which forms the reinforcing of the panels. The railing is reinforced by two ⅜ in. rods running longitudinally, and by a strip of lath laid horizontally. The intermediate panels between the posts are formed by putting on an extra ½ in. thickness of plaster for the raised part of the panels.

The platforms were completely cast before the fences were started, and blocking was inserted to form a trough in which the fences were to be set. After they had been built the joint between them and the platform was covered by carrying a 1 in. granolithic finish up a quarter round curve on to the bottom of the fence. The rods for the posts were set when the platforms were built.

In constructing the fences the lath was held in place by studding of 1 in. angles supported by braces. The plaster was then put on from the side opposite the studding, and after it had set the studding and braces were removed and the other side was

finished. The plaster was made of one part of Portland cement and two parts of sand.

New Dynamometer Car for the Pennsylvania Railroad.*

The dynamometer car for measuring train resistances, recently completed by the Pennsylvania R. R., is the fifth car built by the company for this purpose, has a measuring capacity of 100,000 lbs., and marks the latest development in dynamometer car practice.

Except for the fact that it is a trifle shorter, has but one platform, and that its trucks are of rather unusual design, this car closely resembles the standard passenger coach.

The trucks are of the pedestal type, specially designed to accommodate the deep centre sill. Journal boxes, pedestal jaws and side frames are of cast steel, the latter being rigidly secured to the pressed steel truck bolsters. An 8 ft. wheel base is secured, and 33 in. steel-tired wheels with $5\frac{1}{2} \times 10$ in. journals are provided.

The draft mechanism at the rear or platform end of the car consists of a standard tender coupler in connection with a "Westinghouse" friction draft gear.

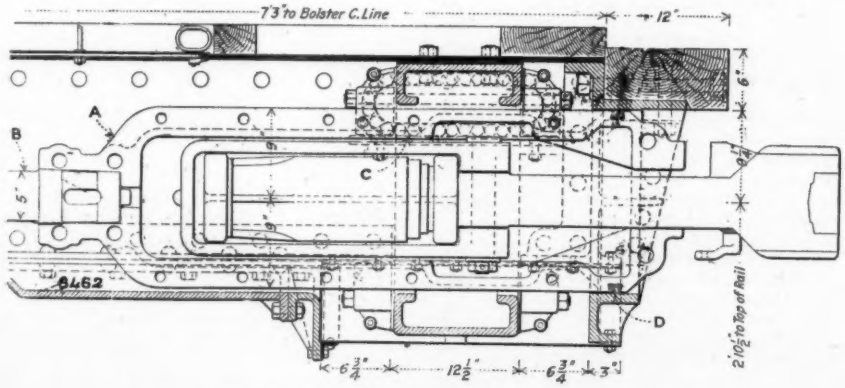
The weight of the entire car is about 62 tons.

The operation of the dynamometer car is as follows: A thrust or pull upon the coupler is transmitted through the drawbar to the piston of a hydraulic cylinder situated within the centre sill about the middle of the car. Pressure in the main cylinder is transmitted to a smaller recording cylinder within the car by means of oil, with which both cylinders and connecting pipes are filled. Movement of the piston in the recording cylinder is resisted by calibrated helical springs, the deflection of which (and resulting movement of the piston) is proportional to the load on the coupler. A pen, actuated by the piston rod of the recording cylinder, marks upon an endless strip of paper, which moves beneath it, an irregular line, whose distance from the datum line is proportional to the load upon the coupler.

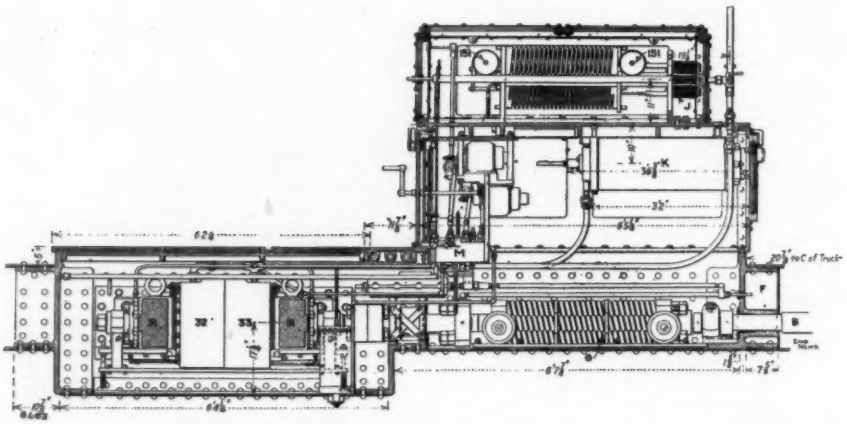
The coupler and friction draft gear (Fig. 1) are secured within the heavy cast steel housing *A*, to which the main drawbar *B* is attached. The housing is guided in the frame of the car by a set of six circuitous ball bearings *C*, parallel to the line of draft, each containing thirty-two hardened steel balls $1\frac{1}{4}$ in. in diameter. Two of these bearings are below, two above, and one on either side, each having ten balls constantly in contact with the housing, thus holding it in rigid alignment without binding. To relieve the dynamometer mechanism from all load when not in use, provision is made for securely locking the housing *A* to the frame of the car by inserting a pair of tapered keys into notches in housing *A*, which, when there is no load on the drawbar, stand opposite corresponding notches in two brackets secured to the frame of the car.

Behind the housing *A*, the drawbar passes through a cast steel partition *F* (Fig. 2), and is connected to the buffer *G*, composed of a nest of thirty-six helical springs, compressed and held at an initial load of 100,000 lbs. The function of the buffer is to protect the dynamometer apparatus from injury in case of loads or shocks of any kind in excess of

* *Engineering News*, pp. 408-410, Oct. 17.



DRAFT RIGGING AT DYNAMOMETER END OF PENNSYLVANIA RAILROAD (FIG. 1).



WORKING MECHANISM OF DYNAMOMETER CAR FOR PENNSYLVANIA RAILROAD (FIG. 2).

100,000 lbs., the normal capacity of the car.

At a point 20 ins. behind the buffer the drawbar connects with the piston rod of the main hydraulic cylinder by means of a coupling. In each end of the cylinder are two automatic valves arranged to transmit the pressure to the weighing mechanism irrespective of the motion of the piston. The recording cylinder, which is connected to the main hydraulic cylinder, is 40 in. long by $2\frac{13}{16}$ in. inside diameter, and has its piston rod connected to a carriage to which is attached the recording springs. This carriage is supported by ball bearing wheels, "151," Fig. 2. A rod extends forward from the frame of this carriage, and carries at its extremity the drawbar pull pen as well as the slotted guide for the arm of the integrator. For supplying oil to the cylinders and taking care of the leakage past the piston a system of tanks, piping and pumps is provided. The paper, or recording mechanism, is driven from the forward axle of the rear truck by means of a pair of spiral gears, the movement of the paper being kept in the proper direction irrespective of the direction of the car by means of gears and a clutch. The paper is drawn off the supply drum at the rate of 1 in. of paper to 100 ft. travel of the car. The zero or datum line is made by means of a small wheel which is in contact with an inking pad, and eight other lines are made, each by an electrically operated stylographic pen. (1) Indicating whether the load is a push or a pull; (2) in circuit with the integrator mechanism, records the area of the diagram between the zero and the pull lines; (3) in circuit with a chronometer, indicates the distance passed in five-second intervals of time; (4) in circuit with a roller which bears against the paper indicates every 1,000 ft. travelled by the car; (5) operated by an observer on the locomotive, records the time of taking indicator cars; (6) operated by an observer on the locomotive, records the steam pressure, also the throttle and reverse lever positions; (7) used to denote locations, such as mile posts, stations, signal towers, curves, tangents, &c. These are noted by the observer at the lookout window, the observer's key being a permanent fixture on the panel of the window; (8) reserved for such extra or special information as the occasion may demand.

For supplying the lighting system, operating the pump motors and recording pens, a storage battery of thirty-two cells is provided. An oil engine and 1·37 k.w. generator is provided to charge the storage batteries when no other means is available.

New Type of Express Locomotive, Northern of France Railway.

There will shortly be put into service on this line a new type of express locomotive having a 4-4-4 wheel arrangement and a special water tube fire box. The water tubes are disposed vertically in the fire box and form a connection between two members

consisting of a steam drum or evaporator at the top inside the fire box, and a water-containing cylinder underneath the grate. Water is supplied to the latter by external tubes of large diameter, having an inlet to the boiler at a position beneath the dome. Water flowing into this and rising in the tubes is evaporated, the steam leaving the evaporator or drum by another large tube, which is led outside the firebox, and arched to enter the boiler, where a connection is made with the main steam pipe leading to the dome. We hope to illustrate this interesting detail in a future issue. The engine which, it should be mentioned, has been constructed by Messrs. Schneider & Co., Creusot, conforms in other respects to the standard practice adopted by the Northern Company in their well-known four-cylinder Atlantics. The pair of trailing wheels has, however, in the new engine, been replaced by a four-wheel bogie.

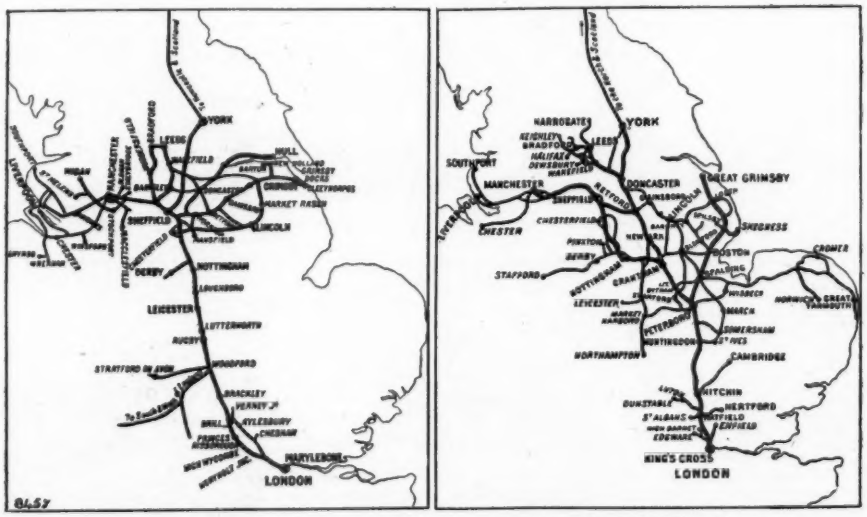
The Great Northern and the Great Central Railways Agreement.

The steps towards a working agreement between the Great Northern and Great Central Railways, of which so much has hitherto been rumoured, have now advanced to within the stage of actual settlement. The text of the agreement submitted to the shareholders of both companies is as follows:

The working agreement between the Great Northern and Great Central Companies is made in pursuance of the Great Northern and Manchester, Sheffield, and Lincolnshire Railway Companies Act, 1858, which authorises the two companies to appoint a joint committee for carrying into effect the purposes of the agreement.

The joint committee appointed by the agreement are in the first place to be composed of the Great Northern and the Great Central directors.

With the exception of the Lancashire, Derbyshire, and East Coast Railway and the Sheffield District Railway, the undertakings of the two companies are to be worked and maintained by the joint committee. Out of the net receipts for each year, after allowing to each company interest at the rate of 3½ per cent. per annum on the duly authorised capital expended or to be expended by such company from January 1, 1907, the joint committee are to pay the sum of £3,803,332 to the two companies in proportion to their net receipts for the year 1906.



Great Central Railway System. Great Northern Railway System.

(From the Railway Gazette.)

SKETCH MAP, SHOWING HOW THE GREAT CENTRAL AND GREAT NORTHERN RAILWAYS OVERLAP.

The net receipts of the two companies for 1906 (subject to slight adjustments) have been agreed as follows:

Great Northern Company ... £2,168,303
Great Central Company ... £1,635,029

Making together £3,803,332

giving (in round figures) the proportions of 57 per cent. to the Great Northern Company and 43 per cent. to the Great Central Company.

Out of the balance of the net receipts if and so far as the same are sufficient in each year, the Great Central Company are to be allowed £100,000 in respect of the capital expenditure by them on certain new lines and works which had not fructified in the year 1906.

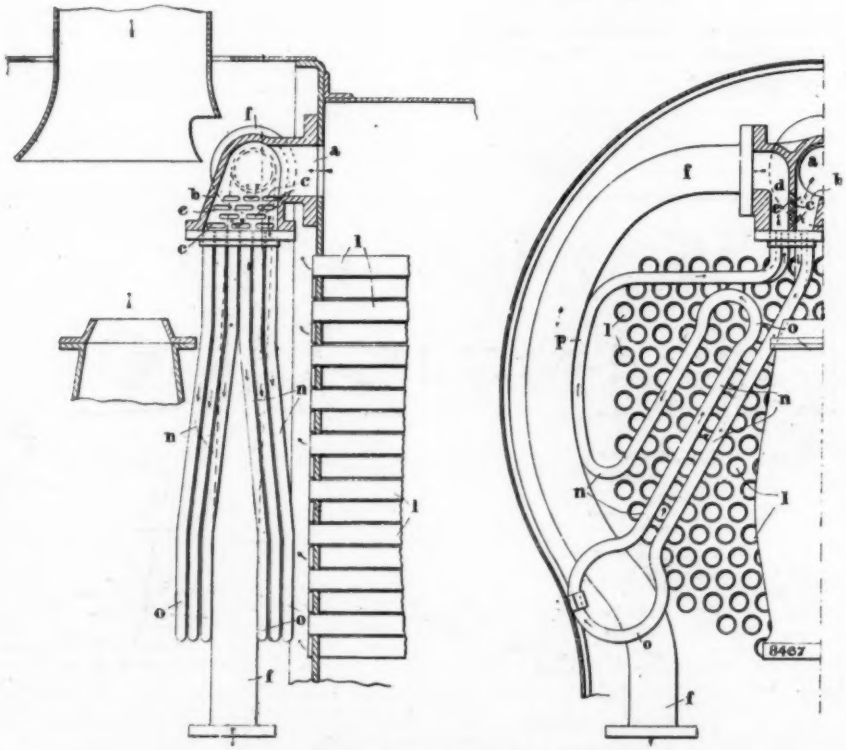
The residue of the net receipts after the payments before mentioned is to be divided between the two companies in the following proportions:—

Down to and including the year 1910, 57 per cent. to the Great Northern Company and 43 per cent. to the Great Central Company.

After the year 1910 and down to and including the year 1912, 56½ per cent. to the Great Northern Company and 43½ per cent. to the Great Central Company.

After the year 1912, 56 per cent. to the Great Northern Company and 44 per cent. to the Great Central Company.

It is well-known that the closest arrangements existed between the two companies prior to the acquisition of powers for an extension to London on the part of the Great Central Company (then the Manchester, Sheffield, and Lincolnshire Railway), a fact which augurs well for the future union. The wisdom of the scheme cannot be doubted, as it will effect important economies without sacrifice of efficiency by the diminution of much competition.



COMBINED LOCOMOTIVE SEPARATOR AND SUPERHEATER.

Combined Separator and Superheater for Locomotives.

There is at present undergoing trial on engines of the Caledonian, North Eastern, Great Eastern and Furness Railways a new type of apparatus in the shape of a combined separator and superheater, which, as is apparent from the illustration, is of simple construction. Its simplicity is, however, no bar to its utility, as we understand that the results so far obtained on the Furness Railway are of a highly satisfactory character. Apart from its qualities as a superheater, the apparatus has effectually cured bad priming on the tank engine, to which it has been applied by Mr. Pettigrew. The apparatus will be seen to consist of a separator interposed in the steam main so as to separate the water carried over with the steam from the boiler; and in combination with the separator is a heater adapted to receive the separated water and to vaporise the same, so that the steam so generated can be fed to the steam which flows to the cylinders, thereby not only ensuring dry steam, but effecting economy.

The steam main *a* is led out through the smoke box end of the boiler as usual and is branched, each branch *b* leading to a separator. The latter consists of a wall *e*, provided with a number of perforations *c*, through which the steam can pass to a branch *d*, thence by the usual steam pipe *f*, to the cylinder. The water carried over by the steam is thereby thrown down into the heater *n*, which consists of tubes led in the manner shown round the smoke box. These, it should be mentioned, are so arranged to allow a cleaning brush to pass into all the fire-tubes.

In the heater the water and wet steam thrown down by the separator is vaporised and, to a certain degree superheated, and passes thence to mix with the steam which flows through the perforations *c*, and so by the steam pipe *f*, to the cylinder. Obviously, when there is but little water thrown down into the heater, steam may pass freely through it being thereby superheated, and supplementing the separated steam which is led direct to the branch *d*, thereby further raising the temperaturing or ensuring dryness.

We hope to publish particulars of tests carried out with the apparatus in a subsequent number.

Workshop Practice

The Fourth Prize Competition closes on January 18. For particulars see page 72.

An Unusual Piece of Machinery.* —In response to the Editor's request that readers would furnish particulars of their experiences of emergency jobs taxing the resources of the shop for the purposes of competition, the following description of an unusual piece of machinery is submitted:

The article shown in Fig. 1 at *A* is a cast iron block, faced at both ends and bored spherically 20 in. radius, the centre of the hemisphere being about 3 inches inside the face (the first 3 inches being bored parallel), making it rather difficult to get at the centre for the boring operation. The lathe available for the job was one of the best of its kind, having a dog-chuck 8 ft. in diameter, and fitted with two slide-rests on the saddle, each with independent feed for the compound slides as well as the feed on the cross traverse.

* Awarded prize, third competition.

The principal difficulty experienced was to find something which would give the necessary radial motion to the tool. This was accomplished as follows:—

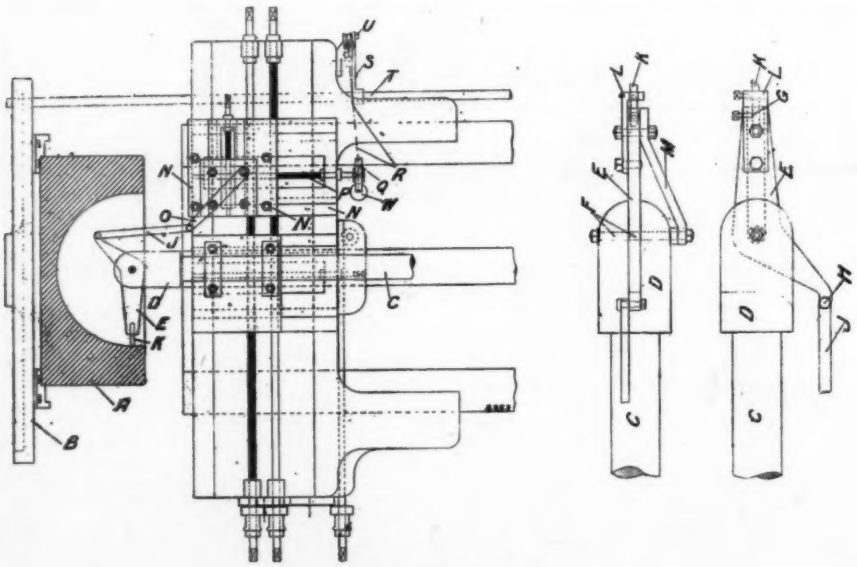
Among the tools which had accumulated during half a century of general engineering work (a great deal of it being of an experimental nature) was found the boring bar *C*, Fig. 2, 6 in. diameter, with a larger piece screwed on to form the head *D*, which had been slotted to receive a tool 1·5 in. thick for the purpose of cutting a 9 in. radius in the blank end of a cylinder 18 in. diameter.

As this appeared to be the only tool likely to be of any use for the job, it was decided to fit it with a tool-holder, as shown in detail at *E*, and sawn from steel plate 1·5 in. thick, drilled to receive *F* the centre pin, at *G* for the tool and set-screw, and at *H* for the joint pin for actuating rod *J*. By some misunderstanding or alteration of design the tool-holder *E* was cut too short, so that the tool *K* would need further support. This was given by adding the bent piece *L* found on the scrap-heap, which only required drilling for the tool and set-screw.

The tool-holder *E* was evidently too weak to take much cut without it needed some support to prevent bending under the strain. The bracket *M*, made of 2 in. by 1 in. flat bar, was found to answer admirably, and altogether this patchwork tool performed the boring operation in the most satisfactory manner.

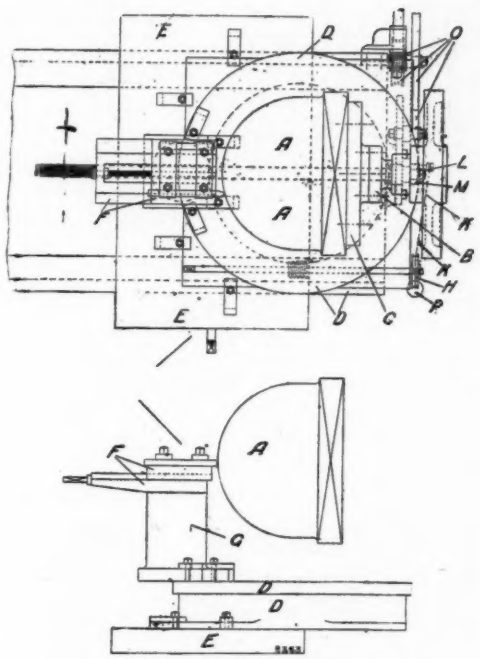
The general arrangement in Fig. 1 will show how the work was done. The female hemisphere *A* was gripped by the six jaws of the chuck *B*, and, after facing, by two bolts and plates, the parallel part was bored 3 in. deep. The top portion of the compound rest was then removed and the bar *C* bolted in its place, so that the centre of the pin *F* was in line with the centre of lathe and 3 in. inside the face of *A*, the tool *K* put in the holder *E*, and the actuating rod *J* connected to the second slide-rest *N* at back of machine by bar *O*, secured by the studs used for the tools.

The feed was obtained by using the chain feed on the slide-rest *N*, the screw *P* being turned by the chain-ratchet wheel *Q*, the chain *R* being actuated by the lever *S* carried on the rocking shaft *T* connected to the head-stock; the chain is connected to the lever *S* by the pin *U*, the chain being assisted on the return stroke of lever by the weight *W*. The feed was not constant throughout the whole travel of the tool, but the difference amounted to so little that after the finishing cut it was not noticeable, and it is remarkable that the job was done with such a small expenditure in the way of tools.



AN UNUSUAL PIECE OF MACHINERY (FIGS. 1 AND 2).

The second item is the cast iron male hemisphere, corresponding to the female except that the parallel portion is slightly longer and is of the form shown at Fig. 3, *A*. The casting is mounted on the mandrel *B* of a horizontal boring machine as shown, *C*, the face-plate of a lathe, being adapted to fit on the flanged mandrel, being secured by four screws and bolted to the casting by four bolts 1·25 in. diameter. The circular table *D*, one of several used for various operations on different machines in the shop, is bolted to the table *E* of the machine, and on it is mounted the slide-rest *F* with its standard *G*. The saddle of the machine is raised to bring the centre of the mandrel level with the cutting edge of the tool. The feed is supplied by the chain-ratchet wheel *H*, actuated by the chain *K*, which in turn derives its motion from the pin *L* secured to the pinion *M*, the latter being driven through the train of gears *O* used for screw-cutting. The screw is disconnected from the table while the hemisphere is being turned, the weight *P* keeping the chain tight between the crank pin and ratchet wheel. The gears are arranged so that the pinion *M* makes one revolution to one of the mandrel, so that the circular feed is regular throughout the cut.



AN UNUSUAL PIECE OF MACHINERY (FIG. 3).

The slide-rest *F* is shown so that the cut can be adjusted when turning the spherical portion, while for turning the parallel part it is moved through a right angle on its standard, so that when the standard is moved to the position for turning it, the slide-rest will be parallel with the centre of the machine.

No special gear was made for the job, all that was done being to adapt the face-plate *C* as stated, the hemisphere being correctly turned to the required radius; the machine being of a heavy make carried the weight on the mandrel without any sign of weakness. M. M. S.

An Urgent Permanent Repair Job: "Hooping a Cracked Flywheel."—On the Saturday preceding the August bank holiday, 1900, we shut down our 375 h.p. factory engine for one week for extensive alterations. Two new compound cylinders, with "Corliss" valve gear, were to be substituted for the two old slide valve cylinders supplied with the engine some years ago. The steam pressure was to be increased from 100 lbs. to 140 lbs. per sq. in., and the speed increased from 60 to 80 revs. per min. By these alterations we were expecting to reduce our coal bill substantially, which we afterwards proved to be correct.

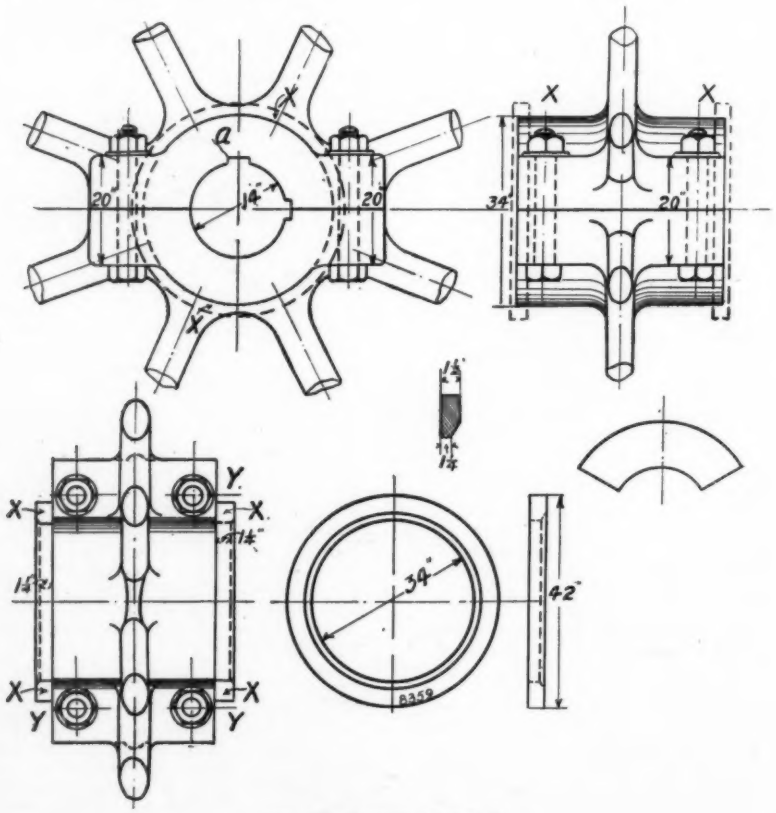
Upon looking over the flywheel hub we found a very dangerous crack extending from the corner of one of the keyways, marked *a* in Fig. 1, which had hitherto escaped our notice. The wheel, which weighed about 20 tons and formed the main belt-driving pulley as well, is of a type seldom met with now for heavy flywheels, and instead of being "staked" on, is bored out to fit the shaft, and has two keyways cut in at right angles as shown, the wheel being cast in halves and secured by bolts in the hub and rim.

Upon discovering the crack we at once realised that it would be dangerous to run the engine when speeded up to 80 revs. per min., if indeed not at 60, so we held a conference on the spot to decide what course to take. To get a new flywheel was out of the question, as we only had a week to complete the job in; besides, even given time, it would cost in the neighbourhood of £400.

Something had to be done at once, so we decided to hoop the hub as shown. We started two men on straight away to chip the two side lugs, which are 20 in. across, to the same diameter as the boss, for a depth of $1\frac{1}{4}$ in., as shown at *Y* in Fig. 3. This was very slow and hard work, but the only way we could adopt. The wheel was butting up against a wall box, only 3 ft. high, carrying a bearing for the shaft, so the man had to crouch down in a very uncomfortable position, but by working until 10 o'clock every night we successfully completed the job by the following Friday night. The hub was dressed round to a true circle by the sheet steel gauge shown in Fig. 7, the bottom radius fitting the crank shaft, which is 14 in. diameter and the top 34 in. diameter, which is the size of the hub. We did the accurate sizing up with a pair of large calipers.

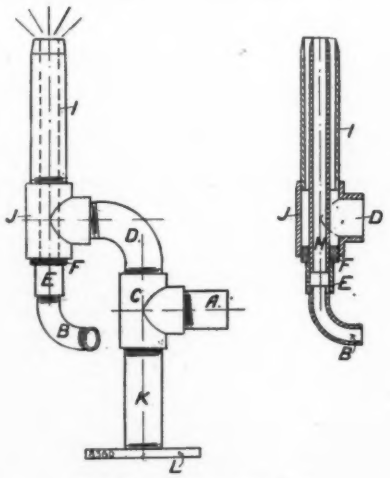
During the time we had been chipping the hub we had been forging the two steel hoops shown in Figs. 4 and 5, also in section at Fig. 6, and marked *X* in Figs. 1, 2 and 3. As soon as we had the hub finished, we made gauges of the diameter and bored the rings $\frac{1}{16}$ in. less, so as to allow plenty of nip when shrinking on; and also turned the rings up all over. These hoops, although only $1\frac{1}{2}$ in. wide where they are shrunk on the wheel, are bevelled off, as shown in Fig. 6, to $1\frac{1}{2}$ in. wide on the outside, thereby being considerably stronger — a very important feature in this case—and well thought out.

On the Saturday morning commenced the work of removing the shrunk on steel

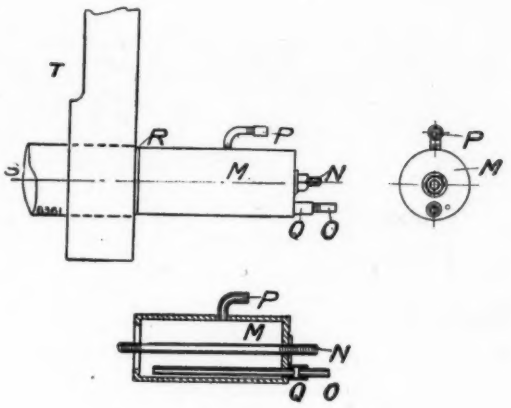


REPAIRING FLYWHEEL (FIGS. 1—7).

crank, by no means an easy task, but we had prepared simple and inexpensive tackle during the week, which did its work effectually and in very little time, and as far as I know is original. Fig. 8 shows a large and powerful gas heater, of which we made two, for heating and expanding the crank. *A* is the air pipe 2 in. diameter, *B* the gas supply 1 in. diameter. The former is coupled up to a pair of portable bellows by indiarubber tubing, and *B* is coupled up in the same manner, to the gas supply; *C* is a tee piece, *D* a 2 in. bend for air passage, *E* is a 1 in. gas coupling, *F* is a plug, screwed tight into *J*; it is also tapped out to receive *H*; *I* is the 2 in. gas pipe for conveying the air to meet the gas, as shown in the section; *K* is a making-up piece, which must be plugged up at the bottom end to prevent escapes; *L* is an ordinary cast iron blank flange with four holes cored in to drive a spike through, for holding down purposes. It will be observed that these heaters were made from standard pipe fittings, no new patterns or new castings being required. These two heaters were placed under the crank, when the latter is straight up, as shown in Fig. 10, and used to expand the crank, whilst a cold



REPAIRING FLYWHEEL (FIGS. 8—9).



REPAIRING FLYWHEEL (FIGS. 10—12).

water pipe played on the end of the shaft to keep the latter cool. The arrangement adopted is shown in Figs. 10 and 11; also in section at Fig. 12. *S* shows the crank shaft, *T* the steel crank; *R* is a rubber ring, *M* is a cast-iron pipe 10 in. diameter by 24 in. long, with a blank end, as shown; *N* is a ⅞ in. stud, which secures *M* to *S* by being screwed into the end, a hole having to be tapped to receive it; *O* is the inlet pipe on the bottom, connected to the town supply and delivering cold water against the end of the shaft, and on becoming heated rises to the top and passes away by the elbow pipe, *P*, on the top. With this rig-up we removed the crank successfully in two hours, and jacked the flywheel and shaft up out of its bearings, heated the two hoops *X* and shrank them on, afterwards heating the crank and shrinking it on again. This we completed by the Saturday night, and got all coupled up on the Sunday ready for running early on Monday morning.

The engine was speeded up 20 revs. per min., and has been running successfully ever since. The flywheel shows no signs of weakness, the steel hoops having closed the crack considerably. It is a sound substantial job, and looks quite as neat and secure as a new flywheel, and is probably more secure, as the hoops are of a special tough quality and made weldless. By effecting this repair we estimate we saved several hundred pounds.

W. D.

LEADING ARTICLES OF THE MONTH—CURRENT EVENTS—TECHNICAL INFORMATION FROM ALL SOURCES.

Heat Radiation and Temperature.

It was formerly thought that the amount of heat radiated was proportional to the temperature difference. Inasmuch as former experimental work was done at low temperatures the error of this assumption was very small. But of late years, since interest has arisen in the quantitative investigation of high temperature furnaces, it has become important to work with the true and recently proved law in mind. This radiation law, known as that of Steffan and Boltzmann, states that if two infinite plane surfaces are close together, or, better yet, if a ball is inside a hollow sphere, both surfaces being in all cases of the same material, in the same state of surface finish, the rate of heat radiation from the hotter to the cooler surface is: Rate of Radiation = $K (T_1^4 - T_2^4)$ where K = a constant for any particular set of bodies and surfaces, T_1 = the absolute temperature of the hotter body and T_2 = the absolute temperature of the colder body. The above equation is equivalent to stating that each body radiates heat and receives heat by radiation; that the rate of radiation from each body is proportiona to the fourth power of its absolute temperature: and therefore that the net amount of heat given up by the hotter body to the cooler one is proportional to the difference of the fourth powers of their absolute temperatures. A bulletin shortly to be issued by the steam engineering department of the U. S. Geological Survey makes a number of applications of this law. Some similar applications relating to a water tube boiler of the "Heine" type are given by *The Engineer*,* Chicago, to whom we are indebted for this information.

Summarising these examples we get the following figures:—

Furnace Temperature. Degrees F.	Tube Temperature. Degrees F.	Number to which Net Radiation is Proportional.
2,039	1,239	31
2,539	1,239	73
3,039	1,239	142

* November 1.

The heat absorbed from radiation practically doubles with every 500° increase in combustion chamber temperature.

The conclusion reached in the case of an ordinary multitubular boiler burning smokeless coal under the boiler shell, is that perhaps half of the heat enters the water from a radiation source. Even in water-tube boilers it may be about 20 per cent. In locomotive boilers the firebox may sometimes absorb perhaps 30 to 50 per cent. of the total heat absorbed, most of this 30 to 50 per cent. being due to radiation.

H.M. Torpedo Boat Destroyer "Mohawk."—A Speed Record.

The latest and one of the most interesting additions to the torpedo-craft of the British Navy is a turbine-propelled, oil-fuel destroyer, 270 ft. long and 25 ft. beam, that has achieved the distinction of establishing a double record in speed and fuel consumption. The builders, Messrs. T. Samuel White & Co., Ltd., East Cowes, have had a wide experience in torpedo-boat construction, and have achieved many brilliant results culminating in the record vessel *Mohawk*. The conditions of the contract were onerous, calling for an average speed, six hours on end, of 33 knots. In her trials over the measured mile at the Maplin Sands, at the mouth of the Thames, the vessel beat all records for lengthened trials by steaming for six hours at a mean speed of 34·245 knots on an oil-fuel consumption 14 per cent. less than the Admiralty specification requirements for a speed of 33 knots. This high-speed capacity has been obtained, too, without the sacrifice of sea-worthiness and reliability or the reduction of radius of action. Rough sea tests have proved the former; and possessing an oil carrying capacity of 148 tons, the fuel consumption being 68¼ tons on the six hours' trial, a simple computation shows that at top speed the radius of action of nearly 432 knots. At 14 knots, or cruising speed, the radius of action will be 1,500. The following table shows the

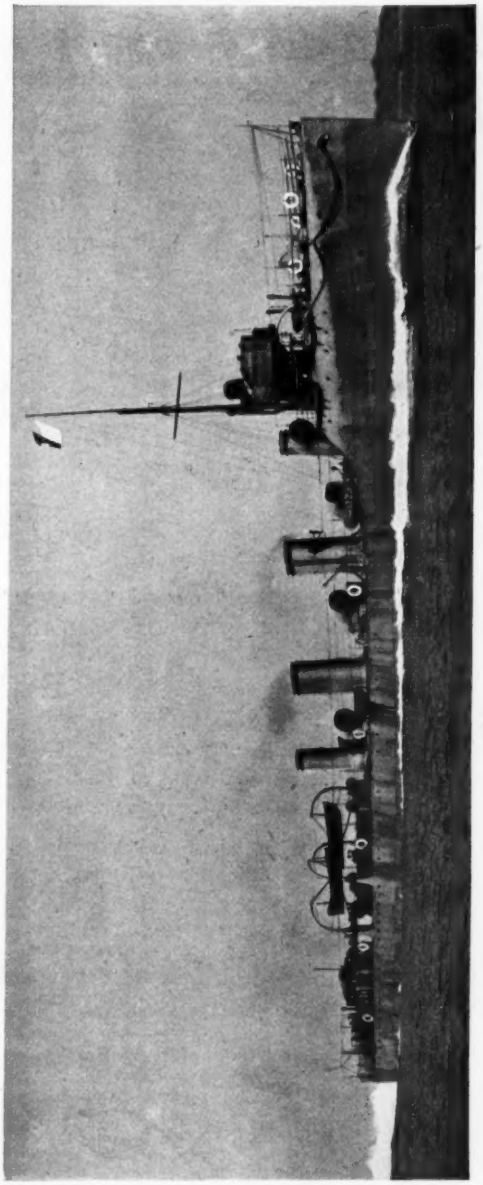
details of the trials for the period of six hours:—

Hours.	Revolutions per Minute. Mean of Three Shafts.	Equivalent Speed Based on Mean Revolutions, and Mean Speed of Six Runs on Mile given above.
		knots.
1	733	33·407
2	750	34·183
3	754	34·365
4	731	34·227
5	731	34·227
6	756	34·455

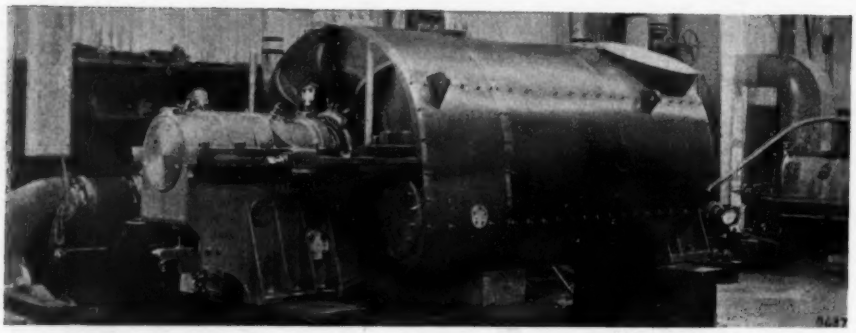
Admiralty Mean of Means.

Revolutions	751·4 per minute
Speed	34·245 knots per hour.
Total oil fuel consumption during the six-hours' speed trial	68¼ tons
Rate per square foot of heating surface per hour	0·86 lb

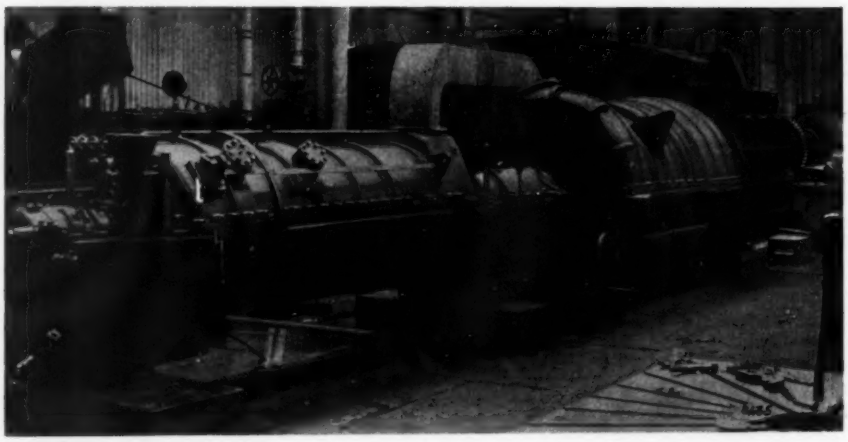
The vessel, as above mentioned, is driven by turbines of the "Parsons" type, views of which are given in the accompanying illustrations. There are altogether seven turbines; a h.-p. cruising, an intermediate cruising, a h.-p. main, and two l.-p. main turbines—all for going ahead, with two astern turbines. One cruising, one l.-p. main ahead, and one astern turbine are mounted on each wing shaft, the h.-p. main turbine being on the centre shaft. They are operated as follows: at full speed the cruising turbines are cut out steam passing direct from the boilers to the h.-p. main turbines, thence to the l.-p. main turbines; at intermediate speeds, the h.-p. cruising turbine is cut out and at low speeds steam passes through all the ahead turbines in the following succession: h.-p. cruising, l.-p. cruising, h.-p. main, l.-p. main. In manœuvring, the l.-p. ahead and the astern turbines are used, and when necessary boiler steam can be passed to any one of the seven turbines. The rotors vary in diameter from 31½ in. in the case of the h.-p. cruising turbine to 44½ in. in the h.-p. main turbine, and 66 in. in the l.-p. The blades vary in length from ⅜ in. to 11 in. Steam is supplied by six water-tube boilers of the "White-Forster" type, arranged in pairs in three boiler rooms. Worked with forced draught they, in combination with the oil-fuel burning apparatus, have adequately proved their efficiency and capacity for both a steady and full speed steam supply. This



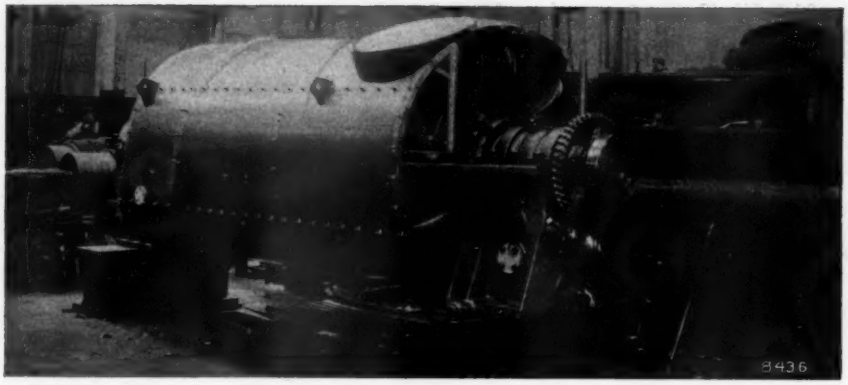
H.M. TORPEDO BOAT DESTROYER "MOHAWK."



HIGH-PRESSURE MAIN TURBINE. FORWARD END.

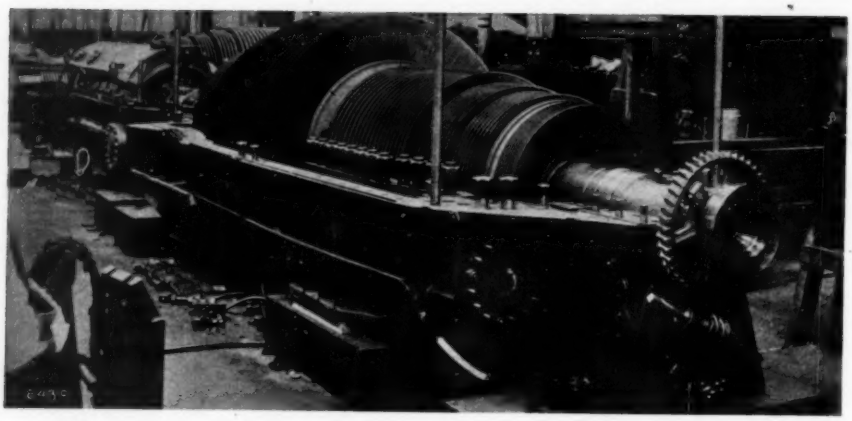


ONE CRUISING, ONE LOW-PRESSURE AHEAD AND ASTERN TURBINE UNDER STEAM IN SHOPS

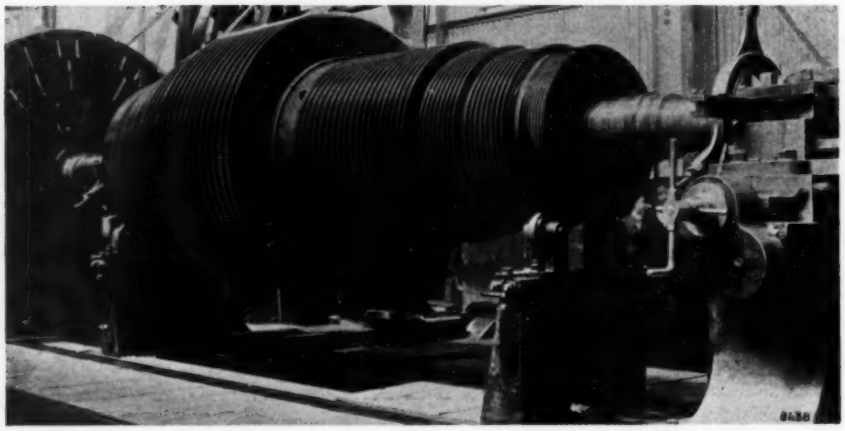


HIGH-PRESSURE MAIN TURBINE. AFT END.

ONE CRUISING, ONE LOW-PRESSURE AHEAD AND ASTERN TURBINE UNDER STEAM IN SHOPS.



CRUISING LOW-PRESSURE TURBINE AHEAD AND ASTERN ROTOR IN CASING.



LOW-PRESSURE AHEAD AND ASTERN ROTOR IN LATHE.

type of boiler has already been dealt with.* We are indebted to the courtesy of Messrs. J. Samuel White & Co., the builders, for the foregoing information and photographs.

The Filling of the New Croton Reservoir.

The 38,000,000,000-gal. reservoir formed by the new Croton dam has recently been filled, and water ran down the spillway for the first time on Nov. 6. This reservoir impounds the water that overflows from the ten dams in the Croton valley above it, and is a lake having a maximum length of nearly 20 miles. During last month it has supplied a daily average of 314,000,000 gal. of water to New York City.

The dam, says the *Engineering Record*, now presents a beautiful appearance on account of the large volume of water pouring over the waste weir, falling in cascades down the spillway to the channel at the foot of the dam, through which it finds its way to the original bed of the river. The overflow sweeps around the end of the main structure, and passing under the 200-ft. arch roadway span, makes a total descent of about 150 ft.

It will be remembered that this dam was commenced in 1892, and was officially completed Jan. 17, 1906, at a total cost of about £1,540,000. It is notable for being the highest and largest dam yet constructed, and contains about 850,000 cu. yd. of masonry, which extends about 150 ft. above the surface of the ground at the foot of the dam and to a nearly equal depth below it, where it has an extreme width of about 206 ft. At the top there is an ornamental cornice and balustrade along the roadway crossing it, the width being about 26 ft. over all, while the minimum width of the dam is 18 ft. The dam is built entirely of granite masonry faced with ashlar, and has at one end a waste weir 1,000 ft. long, nearly at right angles with the axis of the dam, and 16 ft. below its crest. The water flows over the crest of the waste weir into a spillway 400 ft. wide at the upper end and 200 ft. wide at the lower.

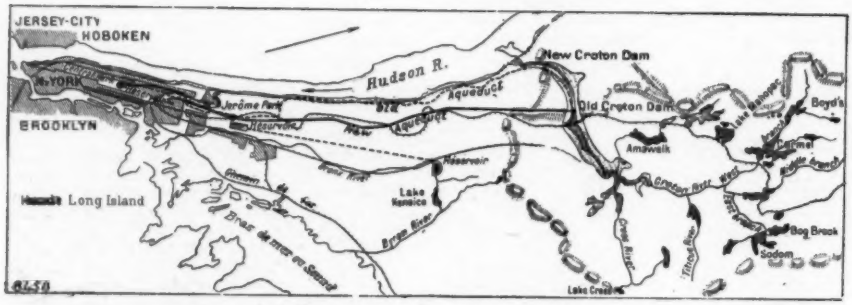
Observations have been made on the tightness of the dam, and no important percolation through it has been observed. A slight seepage does, of course, take place through the masonry, but it is only on dark or cloudy weather that moisture can be observed on the down stream face. This has been noticed to maintain a distance of about 30 ft. below the water level on the upper side of the dam as the latter fluctuates. A very careful examination below the dam fails to show as yet the appearance of any new springs or evidences of leakage through or around its foundations. No indications of change in the ground water level in the adjacent country have yet been observed above the dam, but it is possible that these may later appear.

* ENGINEERING REVIEW, vol. 17, p. 57.

Coal Consumption in Steam Ships.

A brief table which is worth repeating appears in the December number of *International Marine Engineering*, showing in round numbers the

NORTH END OF NEW CROTON DAM, SHOWING WATER DISCHARGING OVER WASTE WEIR INTO SPILLWAY FOR THE FIRST TIME.



MAP SHOWING THE POSITION OF THE CROTON DAM.

increase in coal consumption with the speed up to 30 knots. It is based for both the higher and lower speeds on the assumption that horse-power and coal consumption vary as the cube of the speed. This assumption is not accurately tenable but is the best at hand.

Knots.	Horse power.	Tons per Day.
8	2,039	33
10	3,982	64
12	6,881	111
14	10,927	176
16	16,311	262
18	23,225	373
20	31,858	512
22	42,403	681
24	55,051	885
26	69,992	1,125
28	87,418	1,405
30	107,521	1,728

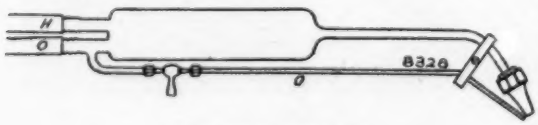
It will be seen that the consumption for 24 knots is 885 tons, close enough to the reputed coal consumption of the *Lusitania*, at this speed, to furnish some sort of proof of the correctness of the table.

A Burner for Cutting Metals.

The existence of a means of opening within a few minutes the largest fireproof safe by a comparatively simple apparatus is not generally known, yet such is the case, the method being that of cutting metals by a burner utilising oxygen-acetylene or oxygen and ordinary illuminating gas. The experiment of burning iron wire in pure oxygen gas is a well-known one, and the step of applying this phenomenon industrially was made some time ago, in the welding of metals autogenously with the oxygen flame. In the application of this method for cutting metals a burner such as is shown in the accompanying figure is employed, by which the oxygen supply is directed to the melting line only, having a diameter of only a few millimetres with sharp edges. The plate to be cut is preheated along the line to be cut with the normal welding flame of acetylene-oxygen, illuminating gas-oxygen, or benzine-oxygen—it does not matter which—and then a strong oxygen current supplied through the additional small tube is directed along this line.

The least expensive is the acetylene-oxygen flame, especially when thick plates are to be cut, since this gas mixture evolves the greatest number of calories per unit of gas volume. In practice, however, illuminating gas or benzine may be used instead of gas or acetylene for the sake of convenience.

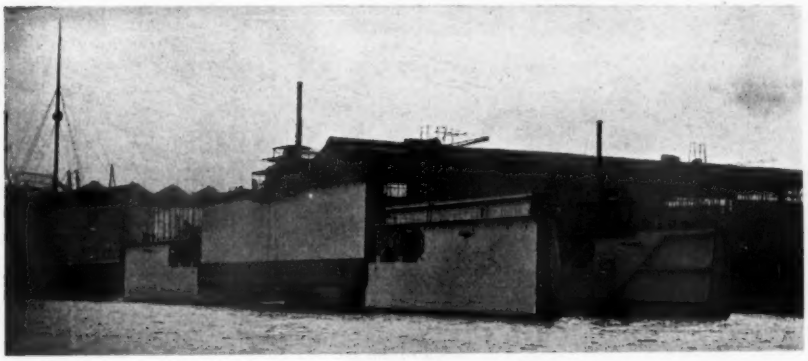
The method is finding an increasing application in the metal industries.



BURNER FOR CUTTING METAL.

Floating Dock for Trinidad.

There has recently arrived at Chaguaramas Bay, close to the Port of Spain, Trinidad, a floating dock of a new type being constructed to provide great longitudinal stiffness. It consists of three portions practically equal in length joined together by joints, bolted in the underwater portion and riveted in the walls. These joints run right round the dock, and are of great strength. the resistance being calculated to equal that of each section of the dock itself. For self-docking operations the three sections are disconnected, the two end lengths being turned right round, lowered under water, and afterwards drawn in, points first, under the central section. The end sections are then pumped out, and rising, bring with them the central part, so that the bottom may be examined or worked upon.



FLOATING DOCK FOR TRINIDAD.

The length of the dock is 340 ft. over the pontoons, or lifting portions, but including the steel working-platforms provided at each end, the over-all length of floor is 365 ft. The clear width of the entrance between the rubbing timbers is 62 ft. The dock is capable of lifting 4,000 tons in fresh water, and it has been designed to take vessels drawing normally 16 ft. of water over keel-blocks 4 ft. high, but a sufficient freeboard has been given to the walls to enable the dock to be sunk to an additional two feet if necessary.

The dock was designed by Messrs. Clark & Standfield, and constructed by Messrs. Swan Hunter & Wigham Richardson, Ltd., Wallsend-on-Tyne.

H.M.S. "Hero" as a Battleship Target.

An interesting experiment was carried out on the last day of November with the *Hero*, a twenty-year old battleship, which was subjected to bombardment by H.M.SS. *Hibernia* and *Dominion*. The main object of the test was to determine how the electrical appliances used in connection with fire control on all recent ships was likely to stand fire in action. The ships mentioned opened fire at 8,000 yards with their 12 in. and 6 in. guns, and in five minutes the *Hero* was listing and settling down by the stern, where she had been struck by a 12 in. shell. After examination of the hull the *Hibernia* alone opened fire, steaming at 15 knots towards the target, and made some fine practice, the effect of the firing being well shown in the accompanying reproduction from a photograph. Although the results obtained have been kept a close secret, it is understood that the electrical connections suffered severely after a very few hits. The dummy men posted throughout the ship and in the firing tops were blown away, the fire control top and after conning tower were hit, the funnel shot away, and the fore wheel house with its barricade of hammocks wrecked. It will be remembered that a similar experiment was carried out with the old *Belleisle* in 1900, the object in that case, however, being to determine the general effect of modern gun fire.

The Machinery Hall and Stadium, Franco-British Exhibition.

Rapid progress is being made with the construction of the buildings of the Franco-British Exhibition, the two accompanying half-tones showing the machinery hall and stadium in the condition they had reached on the occasion of the recent press view referred to in our last issue. These structures are the largest on the site, and are being constructed by Messrs. Alex. Findlay & Co., Motherwell, on up-to-date lines.

The machinery hall covers an area of about 6½ acres, and consists of two main buildings, joined together at the south end by a building of similar construction, the whole forming a U-shaped building in plan. Each side building is 661 ft. long by 130 ft. wide, the cross-building being 302 ft. long by 310 ft. wide, the building having been extended to satisfy the demands for space.

The side buildings are divided into three bays, with a central span of 50 ft. and two outer spans of 40 ft. The outer columns built up of two-channel bars, braced with flat bars and angles, are spaced 13 ft. 4 in., *c* to *c*, and the inner columns of four angle bars braced diagonally with flat bars 26 ft. 8 in. The latter carry the intermediate roof trusses. The roofs, which have raised lanterns running the full

THE EFFECTS OF THE GUN FIRE OF H.M.SS. "HIBERNIA" AND "DOMINION" ON THE OLD BATTLESHIP "HERO."

length, are partially glazed on the Mellowes' system, the remaining portions being covered with corrugated sheeting. The sides of the building are filled with concrete breeze attached to horizontal wall joists. The stadium is an important structure with straight sides and rounded ends, providing seating and standing accommodation for 75,000 people. It is constructed of rolled steel joists, 15 in. deep, spaced 20 ft. apart, and supported by braced screen columns built up of two channel bars, 5½ by 2½, braced on the sides with flat lattice bars. The columns are braced longitudinally and transversely with horizontal channels and diagonal flat bars. The risers consist of channel bars, 9 by 3, of varying weight, according to the span, the latter increasing from the front of the curved ends. They are spaced from 2 ft. 4 in. to 2 ft. 6 in., according to the position, and they are fixed to the rakers by means of forged stools. The platforms consist of reinforced concrete, averaging 2 in. thick, the enclosed steel bars being of the indented type, ⅜ in. square, spaced 12 in. apart. The portion of the building set aside for seating accommodation is roofed over with trusses, 61 ft. 8 in. in span, with an overhang of 17 ft., 10½ in., and the scantling is covered with corrugated sheets.

The Naval Base at Rosyth.

After a long period of uncertainty the Admiralty have now decided upon a work which has been admitted on all hands to be one of urgent national importance, namely, the construction of a naval base at Rosyth, on the estuary of the Forth. The announcement was made by Lord Tweedmouth, the First Lord of the Admiralty, at Duns, on November 30th, from whose speech it is ascertained that the base will include a basin of 56 acres, having a depth of 36 ft. at all tides, and there will be accommodation at the quays for twenty-two warships, or, if double-banked, for forty-four. A dock of sufficient size to take the biggest battleships of modern times is also to be constructed, the whole scheme requiring ten years to complete. At present there is not, according to Lord Tweedmouth, on the east seaboard of this country, a dock sufficient to admit battleships of recent construction, although on the Clyde, the Severn, the Mersey, and at Belfast there are private docks capable of accommodating them, as well as Government docks at Portsmouth and Devonport. The Forth has a splendid railway communication, a good water supply, and is close to the

MACHINERY HALL, AT THE FRANCO-BRITISH EXHIBITION, FRONT ELEVATION (NORTH ARM).

shipbuilding facilities of Leith and Granton, and, in case of emergency, the best of shipwrights and engineers could readily be got from the Clyde, hence the choice of site leaves nothing to be desired. Tests on the site have already been made to a depth of 90 ft., and it is understood that sinking is to be carried to a further depth of 10 ft. to prove the suitability of foundations at this depth.

Practical Applications of Colloids.

Engineers generally have hitherto considered the matter, the colloidal state, as barren of practical results, although this idea is entirely wrong. The colloidal state is now beginning to make itself felt in a great many different fields. According to *Electrochemical and Metallurgical Industry*, Dr. Whitney has showed an instructive application to the dyeing of textile fabrics. Ferric chloride and potassium ferro-cyanide solutions produce Prussian blue on mixing, and this is a colloid whose precipitation may be prevented by removal of the electrolytes which are formed by the reaction, if the solution is not too strong. This removal may be easily brought about by dialysis. This colloidal Prussian blue will not dye or colour a mass of agar jelly suspended in it, nor will it dye cotton—because, as a colloid, it exerts no osmotic pressure, and therefore has no tendency to diffuse. It has no tendency to penetrate the jelly or the cotton. But just for the same reason, if in any way the colloid is produced within the jelly or the cotton, it will be impossible to wash it out. Dr. Whitney demonstrated this in the case of jelly by a sample which was treated first with ferric chloride, and after rinsing, with potassium

REAR VIEW OF STADIUM, FRANCO-BRITISH EXHIBITION.

ferro cyanide solution. The resulting colloidal dye cannot be washed out from the jelly. This exceedingly pretty experiment shows clearly possibilities in unexpected directions. The same periodical states that last year colloids were much spoken of in connection with an entirely different subject, playing an important part in the publications of Dr. Kuzal on his electric tungsten lamp. While other tungsten filaments are made by the "paste" process and by precipitation on carbon cores, Dr. Kuzel claims to make use of tungsten in the colloidal state. How far this is the case in the industrial manufacture of his lamp is not known.

Natural Carborundum or Moissanite.

In an address by Dr. Kunz delivered to the recent general meeting of the American Electro-Chemical Society, Dr. Kunz referred to the renowned block of meteoric iron from Canyon Diablo, Arizona, which was found to be so heterogeneous in its structure and to contain iron, nickel, sulphur, phosphorus, silicon and carbon. The latter element was found to exist in its several forms—amorphous carbon, graphite and diamond, and Moissan succeeded in separating both the black and the transparent variety of the diamond. In connection with these, Moissan discovered, as absolutely new, green hexagonal crystals of carbon silicide. This is the same substance which is so well known under the name of carborundum, and is artificially produced in very large quantities in the electric furnace. As this is the first instance in which carbon silicide has been proved to occur in nature, and, therefore, as a mineral, it is entitled to a distinct mineralogical name, and Dr. Kunz has thought it fit to associate Moissan's name with it and call it Moissanite. Moissanite is therefore natural carborundum, or carborundum is artificial moissanite.

Bright Plated Metal Surfaces.

As a rule, articles plated by the galvanic process—that is, in electrolytic baths—have a matt surface. Microscopic examination shows that this is because the surface is composed of minute crystals which disperse the light reflected therefrom even when they are not oxidised. In plating with copper this is especially noticeable. For many purposes this matt surface is desirable—as, for instance, where it is intended to subject the copper to the action of an acid or other solution, in order to give it a patina, or to produce the effect called "blood bronze," but where a bright surface is desired, it is necessary to resort to some mechanical means, such as burnishing or polishing with the wheel, which, besides delaying delivery, increases the cost of production. The same is the case where iron or steel is plated with zinc; furthermore, the hot process is, for many classes of work, not applicable. According to the *Electrical World*, a process has recently been patented in Germany by which it is intended to produce by electrolytic methods, in baths of ordinary temperature, a bright surface. This is attained by the addition to the bath of glycocides, phloroglucocides or other similar substances, or nitrogenous glycocides or their derivatives; or, instead of these substances, the extracts of plants or barks, as, for instance, althea, panama or licorice extract, which contain the substances above mentioned. The employment of these materials enables the production in the bath, says the patentee, of a brilliant surface on the plated articles, without any mechanical aid. The metal is said to adhere well, so that, for example, zinc-plated iron sheets may be bent backwards and forwards at will without the zinc coming loose, which up to the present has not always been the case with sheets plated by the hot galvanic process.

A Twenty-Four-Century Old Tunnel.

Evidence exists that a work similar to the famous Simplon tunnel, but on a smaller scale, was executed some twenty-four centuries ago. Owing to the bad state of the water supply of Jerusalem, the King ordered a reservoir to be made at the gates of the city, to which water was to be brought from various springs. The Shiloh tunnel, by means of which water was brought down from a source to the east of Jerusalem and poured into the pool of Siloam, was 1,080 feet long, and is in a straight line. It has been learned that work was commenced at both ends of the tunnel, and the direction was altered a number of times. The floor of the tunnel is finished with great care. The width varies from 1·9 to 3 ft., and the height from 3 to 9 ft. There is much speculation as to how these engineers gauged their direction so well as to be able to recognise and correct errors in alignment as was certainly done.—*Iron Age.*

Experiments on Wind Pressure.

At the December meeting of the Institution of Civil Engineers, Dr. Stanton contributed the results of the second part of the research on the distribution and intensity of the pressure of the wind on structures, which was proposed by the committee of the National Physical Laboratory as the first investigation to be undertaken in the engineering department, and was commenced by the author in 1902.

The first part of this research* was the investigation of the resultant pressure and distribution of pressure on flat plates normal to and inclined to the direction of a uniform current of air. As those experiments were made in a channel 24 inches in diameter, the dimensions of the plates were necessarily small, but between the range in dimensions obtained, which for circular plates was from ¼ inch to 2½ inches in diameter, the results indicated that the resistance of geometrically similar plates was proportional to the area of the plates. In the case of dissimilar plates, however, such as square plates and long rectangles, the resistances per unit area differed considerably.

The value of the resistance so found in these experiments on small plates was somewhat smaller than that determined by Dines, Frowde and Langley for plates of the order of 1 square foot in area. For comparison, the values of the constant, K, in the pressure velocity relation, $P = K V^2$, are given in the following table:—

Experimenter.	Method.	Value of K.
Dines	Whirling Table	·0029
Frowde	Moving Carriage	·0037
Langley	Whirling Table	·0033
Stanton	Plate in uniform current	·0027

On the completion of this part of the work, it was decided to make observations on flat surfaces of areas ranging up to 100 square feet when exposed to the wind, since general experience tended to show that in actual winds whose velocity was not uniform over time or space, the mean pressure per square foot on a large surface was considerably less than that on a small one. As a knowledge of this variation in resistance with the dimensions of the structure, if it exists, is all-important in design, the investigation of this problem was made the chief feature of the new experiments.

For the purpose of the work a steel windmill tower was erected in the grounds of the National Physical Laboratory at Teddington. The experimental boards and models of structures were attached to a light framework carried by the cap of the tower, the height of the centre of the boards from the ground being 50 ft. After some preliminary experiments, the method of observation finally adopted was the determination of the constant in the pressure-velocity relation for pressure-boards of varying dimensions and for the models of structures. It was found, as anticipated from a knowledge of the variable character of the velocity of the wind, that single observations were quite worthless for the purpose in view, but that, if for any pressure-board or model about two hundred observations of the velocity of the wind and the corresponding pressure on the board were taken, it was possible to obtain a fairly accurate value of the constant. In these observations the velocity of the wind was estimated from a pair of pressure-tubes, similar to those used by Mr. Dines in his anemometer, placed about 15 ft. above the centre of the board. These tubes were connected by lead pipes to a sensitive water-gauge, of the type used in the author's previous experiments, placed at the foot of the tower. The resultant pressure of the wind on the board was estimated from a measurement of the pressure produced in a closed cylinder of air by the deformation of a thin steel diaphragm forming its cover which was in contact with the centre of the pressure-board. This pressure was also transmitted through lead pipes to the foot of the tower, and there measured by a similar tilting gauge to the one used for the velocity estimations. The simultaneous observations of pressure and velocity were only possible in the short periods of time in which the velocity of the wind was fairly constant. Such periods, lasting from 2 to 5 seconds, were found to occur about once a minute in a fairly steady breeze. The results of these observations on three pressure-boards, one 5 ft. by 5 ft., one 5 ft. by 10 ft., and one 10 ft. by 10 ft., gave practically identical values of the constant in the pressure-velocity relation. In units of pounds per sq. ft. and miles per hour, the mean value of this constant for the three boards was 0·0032. As this value agreed so well with the average of those obtained by previous experimenters when using plates of the order of 1 sq. ft. in area, it was not considered necessary to make experiments on plates smaller than the one 5 ft. by 5 ft. in the present case.

Further observations on the intensity of the pressure at the front and back of the boards appeared to show that the cause of the higher value of the constant, compared with that obtained in the case of the small plates in the 24-in. experimental channel, was the relatively greater intensity of the negative pressure at the back of the boards compared to that at the back of the small plates.

Experiments were also made on a model of a braced-girder 29 ft. long by 3 ft. 7 in. deep, and on a roof model whose sides were 8 ft. by 7 ft. The ratio of the resistance per unit of area of the model girder to that of a square board in the wind was found to be precisely the same as the ratio of the resistance per unit of area of a small model of the girder made to a linear scale of 1 in 42 to a square plate in the experimental channel and uniform current used in the previous experiments. The resultant pressures on the roof were obtained, for both windward and leeward sides, at angles of 30, 45, and 60 degs. inclination to the horizontal, and indicated the considerable suction effects on the leeward side of a roof when the pressure inside the building is augmented from the windward side by open doors or windows. These results lead to the conclusion that the resistance of a complicated structure in the wind can be accurately predicted from a determination of the resistance of a small model of the structure in an experimental channel.

* Communicated to the Institution in December, 1903.

The Tranmere Bay Development Works.

This formed the subject of a paper by Mr. S. H. Ellis, M.Inst.C.E., given at the November meeting of the Institution of Civil Engineers.

The works described comprise two graving-docks, two floating basins, launchways, engineering shops, and other equipment of a new shipbuilding yard, together with the continuation of two town sewers. The works are situated on what was tidal foreshore of the River Mersey; and the first step in their construction was the reclamation of the site. This was effected by a series of three dams: (*a*) A timber coffer-dam, 625 ft. in length, and about 36 ft. in height above the foreshore; (*b*) a temporary concrete wall, 250 ft. in length, and 29 ft. in average height; and (*c*) a clay embankment extending between low and high-water mark. The larger of the two sewers took the form of a culvert 6 ft. 6 in. diameter, and was constructed by tidal work during the period of reclamation. The graving-docks are respectively 708 and 861 ft. in effective length, and are largely cut out of the sandstone rock, with concrete walls above the surface of the rock (on one side only just above dock bottom), or where the rock was defective in character. The entrances are closed by floating ship-caissons. The outer floating basin, the entrances of which are closed by gates, is 15 acres in area, with a depth of water of 31 ft. 7 in. at h. w. o. neap-tides. The quay-walls, respectively 1,000 ft., 850 ft. and 990 ft. in length (besides a frontage wall 460 ft. in length), are of concrete throughout. The longest wall is founded on sand, with bearing piles driven down to rock. The inner basin, entered from the outer, is for shallow-draught vessels, and is 2¾ acres in area. The "Simplex" system of concrete piling was largely used on these works for the column foundations of heavy engineering shops situated on made ground. The frontage-wall, which is founded on concrete piers sunk through 30 to 35 feet of silt to the rock, was formed by grabbing from the centre of wrought-iron caissons, and of hollow concrete monoliths on an iron-cutting edge. Dredging to the extent of about 64,000 cubic yards of rock and silt from the foreshore in front of the entrances was involved.

Iron, Steel and the Foundry.

Conducted by PERCY LONGMUIR.

FOUNDRY PRACTICE.

Titanium in Steel and Iron.—Mr. C. V. Slocum, in a paper before the Pittsburg Foundrymen's Association, is extremely sanguine as to the future of titanium in the direction of improving steel and iron. About 1890 the St. Thomas Car Wheel Co. noticed a peculiarity in certain car wheels made for the Michigan Central Railroad. These wheels drilled readily at the hub, the iron being less granular than usual and in no sense hard. The tread of the wheel could not be ground on a corundum wheel, and in one case half a day's running made no impression on the tread. These car wheels made extraordinary mileage, and one engine wheel made nearly 200,000 miles, and from which not one-eighth of the chilled surface all round was worn. After careful investigation this unusual wearing quality was traced to one of the irons used having been smelted from titaniferous ores. About 1895 Rossi built a small blast furnace at the New York Car Wheel Works in order to experiment with titaniferous iron ore. The results obtained were definite, and showed that titaniferous ores could be readily smelted in the ordinary way if given proper attention and suitable flux. The iron obtained was a remarkably strong grey pig. Later experiments with an electric furnace have resulted in the production of a ferro-titanium in a form suitable for addition to the ladle. Results obtained by such addition are given as follows:—On one inch test bars, between 12 in. supports, the transverse strength of a strong mixture averaging 3,000 lbs. was increased to 3,600 lbs., or 20 per cent., by using only one half of 1 per cent. of the alloy, which in turn contained 10 per cent. titanium. By adding the same amount of alloy to a weak mixture having a transverse strength of 2,100 lbs., an increase of 40 per cent. resulted. Mr. Wm. Cramp states to Rossi that the addition of titanium to their cast iron has shown an increase of 29½ per cent. over their other cast iron, and of 4 per cent. over their cast iron treated with nickel.

It is commonly accepted that chrome, nickel, molybdenum and tungsten add certain qualities to metal, but none of these elements combine with nitrogen. Moissan says the combination of titanium with nitrogen is attended with the evolution of heat: that "it is the only indisputable example of the combustion of an element in nitrogen."

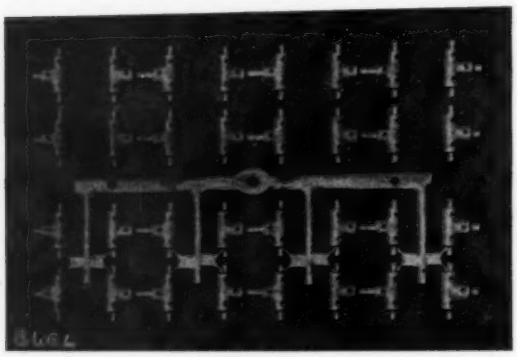
Dr. Weber says that titanium introduced as an alloy at once combines with gaseous nitrogen present in the molten metal, forming a stable nitride. It is the formation of this nitride which prevents the formation of blowholes, and thereby produces solid ingots or castings.

Converter or Small Open Hearth.—The relative advantages of these processes are continually being discussed in foundry circles, and it must be admitted that the discussion fritters on without advancing cogent reasons either way. The fact is that local conditions are nearly always the determining factor, and such conditions cannot enter into a general discussion. Mr. W. M. Carr, who, by the way, is a recognised advocate of the open hearth, is one of the latest to enter this discussion, and a late issue of *The Iron Trade Review* contains the first instalment of his views, which are summarised in the following:—

A steel foundry venture is a money-making project, and the producing unit permitting one to market general castings with the greatest possible margin between production cost and selling price should be the one primarily considered. Low equipment cost on one hand may prove attractive, but higher outlay on the other promises more certain results, less annoyance, and greater profits. The discussion is confined to general steel castings of a carbon range from 0·18 to 0·45 per cent., and the

usual variations in other elements. The production of special alloy castings outside the range given is debatable ground, and it is a question whether the side-blown converter will hold favour over crucible melting. The latter will give almost any range of composition, and a diversified demand can be met with steel by this process as well as by the converter. The simplicity of crucible melting and the low first cost of plant as compared with the difficulties of the converter and its greater initial outlay are points in favour of the crucible process for special work, and in cases of limited demand and intermittent tonnage.

The advocates of the converter base certain claims upon the possibility of producing



MOUNTING PATTERNS.

small light castings. It is conceded that converter steel can be turned out hotter than open hearth metal of similar composition, but it is not granted that converter steel is any better adapted for pouring small castings than open hearth metal. Foundrymen know that if steel is poured too hot the castings are liable to fail or crack because of excessive shrinkage. Steel as it leaves the converter is too hot to pour and must be held or gates added to reduce the temperature. This practice brings the normal casting temperature of the converter process down to the same level as that of open hearth steel.

In Mr. Carr's opinion the high temperature of converter steel is responsible for the heavy losses of the process, and he adds, "no advantage is gained by burning up costly pig iron at the rate of 12 to 30 per cent. per heat, to secure steel which must be cooled before it can be cast into moulds."

In discussing the advantages of the open hearth, the temperature of the metal is stated to be high enough for all practical purposes. It is common practice in open hearth plants to pour from 50 to 100 moulds from a 20-ton heat, and the metal at the end is hot enough to fill light moulds, even pouring them at that stage with fins on the casting not over $\frac{1}{16}$ in. thick.

Gates and Risers.—In the last issue of the *Foundry*, Mr. P. R. Ramp gives a wholesome discussion on risers which may be condensed into the following :—

The feeder or riser must be sufficiently large and effective at its junction with the casting to act as a reservoir and to supply the demand of the casting below. In regard to closed or open risers the writer states that all top and side risers should be closed if the piece being cast is of large size and is made in green sand. With the riser open during pouring, a current of air is formed towards the open riser which does damage in blowing off delicate parts of the mould. A closed riser keeps the air pressure on the surface of the mould and prevents scabbing by tending to hold all parts of the mould in place until covered or reached by the metal. On very heavy castings, requiring some time to fill the mould, unless the air pressure is confined the top surface of the mould will come off in patches and drop before the metal reaches it.

Mounting Patterns. — The opening article in the last issue of the *Foundry* is headed "Production of Malleable Fittings," and is really a description of the methods followed at the new plant of the Morse Iron Works, Erie. Of most general interest is the method of mounting patterns on plates for machine moulding. The machine used in this case is the "Berkshire." For locating and drilling the holes through which the bolts pass for fastening the plates to the table of the machine, a jig is used, and the top and bottom pin holes on the plates which fit over pins on the table of the machine are similarly located and drilled. After this preliminary work the plates are ready for the split patterns, which are of white metal. A plaster cast is made from one half of the master pattern,

and from this an iron mould is obtained in which the requisite number of half-patterns are made. The two half-patterns are accurately fitted together and soldered, and rivet holes drilled right through. The drilled halves are marked or numbered in order to avoid mixing with others intended for the same plate. Half the patterns to be mounted are then placed in position on the plate to insure the best possible method of gating. Holes are drilled in the plate to correspond with those in the half-patterns to be mounted on one side. A template, a trifle wider than half the plate, is then made, having pin holes drilled at the top and bottom to correspond with those in the pattern plate. With the pattern plate as a "jig," holes are drilled in the template to correspond with those made for locating half the patterns on one side of the pattern-plate. The template is then turned over on to the undrilled side of the pattern-plate, and serves as a guide for locating the rivet holes for the other half of the patterns. The half patterns are then riveted to the plate and the gates adjusted. By this method absolute accuracy is assured. The appended illustration will make the foregoing clear; it will be noted that the half-patterns are all on one face of the plate, and that two half moulds from such a plate will make a complete mould.

IRON AND STEEL.

The Steel Rail Question.—The American technical press has of late given much attention to the matter of steel rails, presumably with the object of directing attention to the high breakage ratio. One aspect of the subject is presented in the following summary of conclusions of a report on standard rail sections by a committee of the American Railway Association.* There is a strong tendency on the part of the railroad members to specify a lower phosphorus content than has been generally accepted in recent years, but the evidence of manufacturers is to the effect that available supplies of low phosphorus ores are not sufficient to produce more than a small quantity of the total rail requirements of the country to a maximum phosphorus limit less than 0·10 per cent. On this account producers object to the adoption of 0·085 per cent. phosphorus. A desire was exhibited to arrange for a greater discard, and a strong disposition to insist upon a uniform minimum percentage. However, manufacturers presented evidence tending to show that a fixed minimum percentage requirement would be not only unfair but unscientific, in that the extent of piping and segregation is influenced by the size of the ingot, the rate of pouring and other details of practice. With regard to weight of section, the sub-committee presents sections running under 120 lbs. per yard in weight. It should be remembered that probably not 3 per cent. of the total main track mileage of the country is laid with rails weighing more than 90 lbs. per yard, while there are many thousands of miles of track on first class lines, where the heaviest engines are used, with rail weights ranging from 70 to 85 lbs. per yard; also that it is a generally expressed opinion of railroad men that the older rails of lighter sections are giving more satisfactory service. In the light of this experience railroad men have hesitated to order rails of heavier section, and the same experience is also responsible for the prevalent feeling that modern mill practices are at the bottom of their difficulties. On the other hand, manufacturers claim this charge to be unproven, in that statistics as to comparative wear have not always included details as to tonnage and other conditions, and that reports of breakages and failures are not to be depended on owing to the lack of uniform nomenclature among trackmen of different roads.

A minority report by Mr. J. Kruttschnitt has also been issued, and calls for 0·085 phosphorus and a fixed minimum of discard. In this report the increase in rail breakages are said to be due to:—

1. Unsuitable chemical composition.
2. Insufficient discard, causing concealed defects, which result in breaks in service sometimes with, but frequently without warning.
3. Too great a haste in manufacturing rails, which are finished at too high temperatures, due partly to faulty distribution of material in cross sections and partly to improper manipulation or work on the head in the rolls.

A Further Study of Segregation in Ingots.—Quite apart from its importance on the rail question, segregation is a matter of vital moment, and one on which deeper knowledge is most desirable. Professor Howe records some work in this direction in a recent issue of the *Engineering and Mining Journal*, and from this we condense the following.

At the outset the two questions raised are:—

(1) What is the influence of ingot size? and

* *The Engineer and Mining Journal.*

(2) What is the influence of the rate of cooling on the degree of segregation in steel ingots?

A series of other questions are also raised, but the two given represent the main direction of the paper. It is generally understood that slow cooling by allowing greater time for the migration of impurities to the centre naturally results in greater segregation. Similarly, the larger the ingot the slower the rate of cooling, and therefore the greater should be the segregation. However, Professor Howe's results do not support this, and he shows that increase of ingot size and slow cooling do not always favour segregation. Various reasons are advanced in support of this, and "surfusion" and "quiet" are shown to have a retarding influence on segregation. In the case of "quiet," Talbot's work on the effect of aluminium in retarding segregation is quoted, and as the effect of aluminium is to quiet the steel by allowing it to cool without the evolution of gas, this action would appear to be also that which lessens segregation. Therefore, in summarising, the author states, between the limits of 2¼ in. square and 16 in. square, the influence of ingot size is of such slight importance that it is masked by that of other variables, but the recorded instances of segregation in very large ingots, *e.g.*, those which are 30 in. or more across, indicate that very large ingot-size increases segregation. In most cases there is more segregation in ingots cooled quickly than in those cooled slowly. The direct effect both of an increase of ingot size and of slow cooling should be to increase segregation. The fact that they do not do so under the conditions of the author's tests indicates some secondary but powerful cause at work in the opposite direction. The cause offered in explanation is the quietness to which both large ingot size and slow cooling lead. This quiet should restrain segregation by favouring the land-locking type of solidification directly by lessening the convection currents and the evolution of gas, and at times indirectly and even more strongly by leading to surfusion.

By ANDREW STEWART, A.M.I.E.E.

The Development of British Water-Power.

The last hydro-electric scheme to be noticed in these columns was that of the North Wales Power Co., where a large amount of power, developed from water gathered in the catchment area around Mount Snowden, was used for operating a light railway, and for industrial purposes, such as quarrying.

Water-power development for quite a different purpose is found at Foyers in Scotland, and there are minor installations in the West of Ireland, devoted chiefly, in the latter case, to the manufacture of carbide of calcium, for which there is a good demand, and as the rainfall is considerable and the district rugged, there is no reason why this demand should not be met with carbide made in Ireland, where it can be produced quite as cheap as elsewhere, particularly as the development costs are often small.

Of greater importance is the Loch Leven power scheme, which is now making satisfactory headway, Messrs. Sir John Jackson, Ltd., who are contractors for the dam and the hydraulic work, having made good progress with it. It is expected that part of the plant will be in operation in a few months, producing aluminium in a temporary factory until the larger scheme is in operation.

A dam rather more than three-quarters of a mile long, 80 ft. high, 63 ft. wide at the base, and 10 ft. wide at the top, is being erected 5½ miles from the head of the loch, which

will raise the level somewhat and increase the area under water, the length of the loch being increased to 9 miles. It is expected that some 35,000 h.p. will become available.

The power house and factory is at Kinlochleven, near the sea, and the water is conveyed to the power house, first, by a conduit 4 miles long, and then by a pipe line a mile and three-quarters long.

Ferro-concrete construction will be used for the conduit, the concrete being reinforced by expanded metal sheets. It is 8 ft. square, and is covered in so that it resembles a square pipe.

In order to start the production of aluminium early in the new year, a temporary wood conduit 3½ ft. diameter is being constructed to take a supply of water from an adjoining river to the power house.

Another and an equally ambitious, though not as well advanced, scheme is to come before Parliament in the coming session. The proposal is to dam up Loch Awe, in Argyllshire, one of the largest Scottish lakes, being 28 miles long by 2 miles wide. This dam will be constructed across the River Awe close by the entrance to the well-known Pass of Brander. The average level of the loch is 118 ft. above the sea level, and the dam will not seriously alter the present water line of the loch, though it will submerge a part of the land where the river Awe at present leaves the loch.

An open canal two miles long is proposed, and thereafter a pipe line to the power house, which will be built at the sea near Bonawe Ferry.

A feature of the new scheme is that a large factory, producing ferro-silicon—the raw materials of which are quartz or sand, scrap iron, and coke or charcoal—by means of the electric furnace, will be built on Achnacree Moss, some ten miles from the power house, involving overhead cables which cross Loch Etive, an arm of the sea. Charcoal for the furnaces will be obtained from peat, of which there is an abundant supply in Achnacree Moss. There is plenty of quartz in the igneous rocks of the neighbourhood, whilst the scrap iron can be cheaply delivered by sea.

The electric furnace has rendered possible so many new combinations, and made many older compounds commercially practicable by the economical process of manufacture which it has made possible, that many new industries will spring up in districts hitherto considered altogether unsuitable for industrial enterprise. The limitation of industry to districts convenient to cheap coal, and the consequent congestion of such districts, will become a gradually diminishing feature of industrial development. As the demand for the products of the electric furnace increase, many new undertakings of a similar nature will be developed. A surprising feature of the present situation is that in view of the rapidly growing use of carborundum, and the large imports of this material, a greater effort is not made to produce it here. The raw material we have in abundance, and the cost of equipping a factory on a large scale is as low in this country as in any country in the world.

Electromobiles for City Traffic.

The past few weeks have been unusually interesting to those interested in mechanical road traction, chiefly because the electrically propelled vehicle has once more come to the front, in the columns of the newspapers and technical press. Its presence in the former may be due, not so much to any particular merit in the system, as to the novelty of the method of propulsion, and the absence of anything more sensational to fill the space.

The report of The Electrobus Co. gets premier place, and it has to be said that the directors have so far made out a good case for themselves. They have done many things they said they would do, some of them better than they expected, and as a result are thoroughly well pleased. Those who criticised the scheme—and we ourselves did our share—must of necessity be wrong, and hide their diminished heads in future.

An examination of the directors' report does not, however, justify the cheerful optimism which has been displayed. As to public appreciation of the service of electric omnibuses, there can be no doubt whatever. The ratio of operating expenses to receipts, viz., about 64 per cent., is also very good. They have, moreover, done for 3/- what they expected to cost 4/-, all of which is very gratifying.

We will not dwell on the fact that the criticism of the press led the company to seriously modify many of their proposals, saving £20,000 on one item alone, but confine ourselves to an important detail on which the directors give least information viz., the maintenance and depreciation of the cells. It is all very well to inform the shareholders that the company have unexpired contracts for three years at 2*d.* per mile, but we have no information as to what will happen at the expiration of that period. Everyone does not know that owing to the rapid decline in the capacity of the negative plates, a battery

will require to have all the negatives practically renewed at the end of three or four years, depending on the nature of the work. The type of battery employed by the Electrobus Co. while among the best of their kind, are no more exempt from this item of depreciation than are any others.

We are not told that this 2*d*. per mile includes depreciation and renewals, indeed it is unlikely that it will do more than include the renewal of plates that have become damaged due to chemical or mechanical causes in the day's work.

We are told that no depreciation has been allowed for, which leads us to infer that, as depreciation is the most important item in accumulator traction, the accounts would bear a different aspect if this were included: it may even wipe out the substantial margin which at present exists between operating expenses and receipts, especially when administration charges, which do not appear to be included in the present working costs, are added.

We should welcome any attempt to place electric traction of any kind on a substantial basis, and if we saw any indication of ultimate commercial success in this instance we should not fail to say so, but despite the opinion of Sir Douglas Fox, we see no reason for the optimism of a directorate who come before the shareholders and congratulate them on the results of fifteen months trading, after leaving out administration expenses and depreciation, the latter being far more important in accumulator electric traction than in an ordinary business undertaking, and moreover, the item which has wrecked every attempt to operate accumulator propelled vehicles on a competitive basis.

The Electromobile Company have also held their annual meeting, and disclose a very satisfactory position, but not one from which much data in support of accumulator omnibuses can be obtained. These vehicles are to a certain extent on a non-competitive basis, they are used by those who can, and do, pay a price per mile run which is ample to secure a fair remuneration to the shareholders after meeting all charges. People prefer to pay more for the hire of an electromobile than a petrol car, because they can afford the extra cost of more luxurious travelling, and it is admitted by those who own such cars, that the electrically propelled vehicle, when all charges are figured, costs more to operate than the petrol car, indeed if its sphere of operation was limited to competition on a strictly competitive basis it would cease to exist, and are we to suppose that, while the travelling superiority of the electric pleasure vehicle and its greater maintenance and operating cost are admitted, the results will be different on an omnibus? The latter has to earn its money on strict commercial lines in competition with steam, petrol-electric, petrol, and horse-drawn omnibuses, and the travelling public while they certainly prefer the electrically propelled vehicle, are not prepared to pay more for the extra comfort of an electrobus.

We have dealt with this matter at some length, for there is a very great deal of misapprehension regarding the commercial possibilities of the electric vehicle. It will probably be found, after *all* charges have been met, that the electrobus costs more to operate than the petrol bus; whether its greater popularity will raise its earning power in the ratio of the increased operating cost, time alone can show, but as far as can be seen, there is nothing to justify such an assumption.

The Comparative Performance of Steam and Electric Locomotives.

One of the most interesting contributions to the literature bearing on this subject is the paper bearing the above title, read a short time ago to the American Institute of Electrical Engineers by Mr. A. H. Armstrong. In this paper, the fundamental reasons for the substitution of the steam by the electric locomotive were outlined. Unfortunately, however, the author soon leaves the general question, for the more particular question of the relative performance of steam and electric locomotives on grades, and on lines where the profile of the line is irregular.

He shows, among other things, that while there is always a saving of fuel and other operating expenses with electric traction, this saving increases appreciably with heavy and frequent gradients, which may lead to the electrification of lines operating in districts possessing such characteristics long before it is deemed commercially expedient to electrify lines covering level ground, or merely small gradients. This seems to justify the action of the management of the Southern Pacific Railway in deciding to electrify the section of their line which crosses the Sierra Nevada Mountains.*

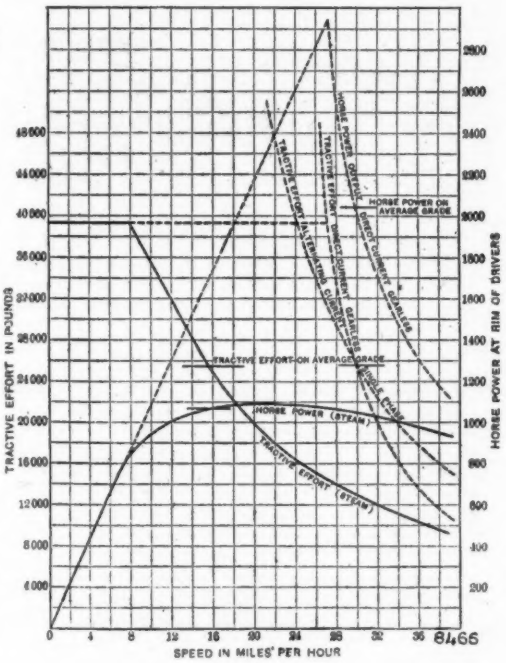
The author of the paper dealt with the various improvements in steam locomotives and their tendency towards complication in

* See these notes, December issue, page 404.

order to secure small, and sometimes even doubtful economies. Compounding, while advantageous under certain circumstances, seemed to be looked upon with disfavour for handling traffic on heavy grades.

The electric locomotive, while it rendered possible the use of very high grade power generating apparatus, and the great economy of condensation, dispensed with the standbye losses of the steam locomotive, which in the aggregate is considerable, and amounts to a very appreciable percentage of the total on a mountain line subject to blocks, and where the traffic renders necessary the rearrangement of trains at various stations. These are, of course, arguments which carry more weight in America than in this country.

Fig. 1 shows the relative characteristics of steam and electric locomotives, the steam locomotive being a simple locomotive with cylinders 22 × 30 driving on to 57 in. drivers, though whether the engine has four or six-coupled driving wheels does not appear from the paper. This locomotive is compared with a direct-current gearless locomotive, and a single-phase alternating current geared motor.



These curves bring out very clearly the small speed variation with different tractive efforts delivered by the electric locomotive, this being even more marked in the case of the direct-current locomotive than in the case of the alternating current locomotive, which, by reason of the lower density of the magnetic induction in the motors, has a more sloping speed characteristic.

The author, in his reference to steam locomotives, remarked that the largest locomotive yet constructed was a "Mallet" compound capable of giving continuously 2,180 h.p., and weighing 300 tons.

An electric locomotive for the New York Central Railway giving the same output weighs only 100 tons.

One of the outstanding advantages of electric traction was greater safety and economy in the operation of mountainous lines. The safety of a steam train depended on friction between the wheel and the brake block, resulting in overheating of such parts, breakages, and danger of derailment. The descent of long heavy mountain lines sometimes results in the blocks and wheel rims becoming heated to a dull red.

Electric locomotives rendered practicable the regeneration of some of the energy lost on the down grade by using the energy of the descending train to drive the motors as generators, and so return to the line much of the energy which would otherwise be lost at the brake blocks, and entirely eliminating the risk of derailment due to broken parts of the brake gear.

In conclusion the author of the paper asserted that while the time was not ripe for the general electrification of steam railways, the problem which electrical engineers had before them was to tackle the most promising field for the operation of electric locomotives. Electricity was recognised as an economic necessity for suburban railways, and the next step was to attack the steam locomotive in mountainous districts.

In this section is presented every month a list of the more important articles appearing in the Engineering Press and of the leading papers read before the various engineering institutions. Full names, addresses, and published prices of the publications indexed are printed each half-year in the volume index.

Civil Engineering.

Land Reclamation in Holland, I., II. *Engineer*, *15th* and *29th November*, 1907.

The Compressive Member. By H. E. Horton. *Railway and Engineering Review*, *2nd November*, 1907.

The Reconstruction of the Anchor Piers of the Poughkeepsie Bridge. *Engineering Record*, *9th November*, 1907.

Floating Dock at Rotterdam. *Engineer*, *6th December*, 1907.

Empiricism and Error in Arch Design. By Chas. W. Comstock. *Engineering News*, *28th November*, 1907.

The Italian Approaches to the Simplon Tunnel. *Engineering*, *22nd November*, 1907.

The Lacing of Compression Members. *Engineering News*, *7th November*, 1907.

Effects of Changes in Canal Grades on the Rate of Flow. *Engineering News*, *21st November*, 1907.

Roofs, V. *Railway Engineer*, *December*, 1907.

The Proposed Henry Hudson Memorial Bridge at New York. *Engineering Record*, *23rd November*, 1907.

The Longkey Viaduct of the Florida East Coast Railway. *Engineering Record*, *23rd November*, 1907.

The Manhattan Approach of the Blackwell's Island Bridge. *Engineering Record*, *23rd November*, 1907.

The Marien Bridge over the Danube Canal at Vienna. By K. Rosenberg. *Zeitschrift des Oestereichischen Ingenieur und Architekten, Vereines*, *22nd November*, 1907.

The Building of the Sanganeb Lighthouse, Red Sea. *Bulletin of the Society Civil Engineers (France)*, *August*, 1907.

Screw Shaped Access Viaduct to the Pont d' Austerlitz. Crossing of the Seine by the Metropolitan Line (No. 2 South). *Le Génie Civil*, *7th December*, 1907.

Building.

A Ten-Story Reinforced Concrete Building. *Engineering News*, *7th November*, 1907.

Waterproof Cellar Construction. By C. A. MacClure. *Proceedings Engineers' Society, Western Pennsylvania*, *November*, 1907.

Heating and Ventilation.

Materials and Measurements.

Requirements for Treating Wood Paving Blocks. *Engineering Record*, *16th November*, 1907.

Zinc Oxide. *The Railway and Engineering Review*, *30th November*, 1907.

Notes on the Effect of Work and Time on the Properties of Mild Steel and Iron. By. J. H. Heck. *Proceedings North East Coast Institution of Engineers and Shipbuilders*, *29th November*, 1907.

Ferro-Concrete and its Applications to Engineering Construction. By J. S. E. De Vesian. *Proceedings of Civil and Mechanical Engineers Society*, *December*, 1907.

Classification and Uses of Cement. By Samuel S. Sadler. *Journal Franklin Institute*, *November*, 1907.

Boilers, Furnaces, and Fuel.

The Ziegler System of Peat Utilisation. *Engineering*, *15th November*, 1907.

Modern Power Gas Producer Practice and Applications. By H. Allen. *Practical Engineer*, *22nd November*, 1907.

Methods of Vaporising Liquid Fuels, used with Internal Combustion Engines as applied to Road Vehicles. By R. T. Deane. *Transactions Institution Civil Engineers*, *6th December*, 1907.

Steam Boilers (*continued*). *Practical Engineer*, *29th November*, 1907.

Meyer's Liquid Fuel Apparatus. *Marine Engineer and Naval Architect*, *December*, 1907.

Materials for the Control of Superheated Steam, By M. W. Kellogg. *Stevens' Institute Indicator*, *October*, 1907.

Engines and Motors.

Gas Engine Peculiarities as compared with those of the Steam Engine. By Horace Allen. *Electrical Engineer, 15th November*, 1907.

Quick Revolution Engines. *Mechanical World, 15th November*, 1907.

Engine and Boiler Trials, IX. *Mechanical World, 29th November*, 1907.

Steam Turbine Construction, II. By T. Franklin, *Mechanical World, 29th November*, 1907.

Control of Internal Combustion for Gas Engines. By Prof. C. E. Sucke. *Proceedings American Society Mechanical Engineers, November*, 1907.

A Study of the Heat Losses in a Gasoline Engine. By Prof. A. J. Wood. *Stevens' Institute Indicator, October*, 1907.

The J. Zoonicek Steam Turbine System. *Elektrotechnik und Maschinenbau, 24th November*, 1907.

Hydraulics and Compressed Air.

Centrifugal Pumps. Some Reasons why Modern Designs are more Efficient. By E. F. Doty. *Engineer, Chicago, 1st November*, 1907.

Centrifugal *v.* Reciprocating Pumps for Domestic Water Supply. By E. F. Doty. *Engineer, Chicago, 2nd December*, 1907.

Notes on Centrifugal Pumps, III. *Mechanical World, 22nd November*, 1907.

The Design of Hydraulic Accumulators. By N. S. Trustrum. *Practical Engineer, 29th November*, 1907.

The Chicago Avenue Pumping Station. A most Complete and Handsome Station, with capacity of 75,000,000 gallons in 24 hours. *Engineer, Chicago, 15th November*, 1907.

Centrifugal Pumps. By E. F. Doty. *Engineer, Chicago, 15th November*, 1907.

The Roturbo Centrifugal Pump. *Le Génie Civil, 9th November*, 1907.

Shop Equipment and Practice.

Acme and Square Thread Taps in Sets. *Machinery, November*, 1907.

Notes on Mill Power Plant, XVI. By C. J. Kavanagh. *Mechanical World, 15th November*, 1907.

A Grinding Spindle for the Lathe. *Mechanical World, 15th November*, 1907.

Notes on the Manufacture and Upkeep of Milling Cutters. By Dr. H. T. Ashton. *Transactions Institution Mechanical Engineers, 20th December*, 1907.

Miscellaneous Mechanical Subjects.

Some Grinding Problems. *Engineering, 15th November*, 1907.

Power Required for Cranes and Hoists. *Machinery, November*, 1907.

A Plant for Making White Portland Cement and Using Producer Gas for Fuel. *Engineering News, 7th November*, 1907.

An Unusual Coal and Ash-Handling Equipment for a Power Station. *Engineering Record, 9th November*, 1907.

Modern Practice in Wire-Drawing Machines, III. *Engineering, 29th November*, 1907.

Some Limitations of Moulding Machines. By E. H. Mumford. *Proceedings American Society Mechanical Engineers, November*, 1907.

Duty Test on Gas Power Plant. By J. R. Bibbins. *Proceedings American Society Mechanical Engineers, November*, 1907.

Coke Drawing Machines and Other Machinery for Use at the Ovens in the Manufacture of Coke. By W. W. Macfarren. *Proceedings Engineers' Society, Western Pennsylvania, November*, 1907.

Locomotive and Railway Engineering.

The Application of Highly Superheated Steam to Locomotives, IV., V., VI., VII. *Engineer, 15th, 22nd, 29th November*, and *6th December*, 1907.

Eight-Coupled Mineral Locomotive for the Hull and Barnsley Railway. *Engineering, 15th November*, 1907.

Causes of Defects and Failures of Steel Tyres (*continued*). By G. L. Norris, *Railway Gazette, 15th November*, 1907.

The Predetermination of Train Resistance. By Prof. Carus-Wilson. *Transactions Institution Civil Engineers, 10th December*, 1907.

Express Passenger Atlantic Type Locomotive for the North British Railway Company. *Engineering, 6th December*, 1907.

Automatic Cab Signalling on Locomotives. By J. Pigg. *Transactions Institution Electrical Engineers, 17th October*, 1907.

Kimball Concrete-Steel Sleepers. *Railway Engineer, December*, 1907.

The Locomotive from Cleaning to Driving, XI. By Jno. Williams and Jas. T. Hodgson. *Railway Engineer, December*, 1907.

Vacuum Automatic Brake Trials on the Austrian Imperial State Railways. *Railway Engineer, December*, 1907.

Steel Rails. *Railway and Engineering Review, 16th November*, 1907.

Protection of Railroad Bridges against Brine from Refrigerator Cars. *Railway and Engineering Review, 16th November*, 1907.

Motor Engineering.

Motor Car Repair. *Mechanical World, 15th November*, 1907.

The Reavell Air Compressor. A Compact Mechanical Pump for Tyre. *Automotor Journal, 23rd November*, 1907.

The 1908 White Steam Cars. A New External Thermostat and other Minor Improvements. *Automotor Journal, 23rd November*, 1907.

The Westinghouse Carburetter. *Autocar, 23rd November*, 1907.

Malleable Castings for Motor Cars, IV. By P. J. Giron. *Mechanical World, 6th December*, 1907.

The Holden-Elphinstone Electric Timing Apparatus. *Automotor Journal, 7th December*, 1907.

Gas Analysis and Carburation. By W. R. Ormandy and J. H. Lester. *Autocar, 7th December*, 1907.

The Certus Friction Drive Car. *Autocar, 30th November*, 1907.

The Relation between Power and Spark. A Comparison between Accumulator and High Tension Magneto Ignition. By W. Watson. *Autocar, 30th November*, 1907.

Electric Lighting.

The Comparison of Glow Lamp Standards of Different Countries. *Electrical Engineering, 5th December*, 1907.

The Tantalum Lamp with High Resistance Filament. *Electrician, 22nd November*, 1907.

The Electrolytic and Metallic Arc. By Isador Ladoff. *Illuminating Engineer, December*, 1907.

Electrical Generation and Transmission.

The Development of Turbo-Generators. By Dr. R. Pohl. *Transactions Institution Electrical Engineers, 17th September*, 1907.

Three-Phase Power Transmission without Switchgear. By R. Coryton Roberts. *Electrical Engineering, 14th November*, 1907.

Aluminium as a Substitute for Copper for Electrical Transmission Purposes. By J. B. Sparks. *Electrical Review, 15th November*, 1907.

Long Island City Power Station of the Pennsylvania Railroad Company (*continued*). *Engineering, 6th December*, 1907.

The Theory of Alternate-Current Transmission in Cables. *Electrician, 6th December*, 1907.

The Calculation of Copper Conductors for Alternating Current Three-Phase Transmission Lines. By F. B. Brown. *Transactions Canadian Society of Civil Engineers, 7th November*, 1907.

The Torque Conditions in Alternate Current Motors. By V. A. Fynn. *Transactions Institution Electrical Engineers, November*, 1907.

The Urft Dam and Hydro-Electric Power Distribution. *Engineering, 29th November*, 1907.

The Leakage of Induction Motors. *Electrician, 29th November*, 1907.

Transmission System and Sub-Station of the Dunedin City Corporation, New Zealand. *Electrical World, New York, 30th November*, 1907.

A Phenomenon of Revolving Field Generators. By F. Punga and W. Hess. *Electrical World, New York, 16th November*, 1907.

Direct-Current Turbo-Generators. By H. I. C. Beyer. *Electrical World, New York, 16th November*, 1907.

Hydro-Electric Generating Station on the Waipori River in New Zealand. *Electrical World, New York, 23rd November*, 1907.

Abnormal Primary Current and Secondary Voltage on Placing a Transformer in Circuit. *Electrical World, 23rd November*, 1907.

Electric Traction.

Corrugations on the Upper Surface of Rail Heads. *Electrician, 15th November*, 1907.

Changing Resistance: Steps to Eliminate Fuse and Controller Troubles. *Street Railway Journal, 2nd November*, 1907.

Standard Location for Third-Rail Working Conductor. *Street Railway Journal, 9th November*, 1907.

Pantograph Collector for High-Speed Electric Railways. By J. Mayer. *Street Railway Journal, 9th November*, 1907.

Report on Rail Corrugation Presented at the Eleventh Annual Meeting of the German Street and Interurban Railway Association. *Street Railway Journal, 9th November*, 1907.

Foundation Brake-Gear, Design for Electric Railway Cars. *Street Railway Journal, 30th November*, 1907.

The Use of the T Rail in Cities. *Engineering Record, 9th November*, 1907.

Some Disputed Questions concerning Steel Rails. *Engineering Record, 30th November*, 1907.

Railway Electrification in Melbourne. *Railroad Gazette, 22nd November*, 1907.

Standard Location for Third Rail Conductors. *Railway Gazette, 22nd November*, 1907.

"Pay-as-you-enter" Cars for a New York City Street Railway Line. *Engineering News, 21st November*, 1907.

The Manufacture of Steel Rails and Proposed Changes in Section. *Engineering News, 21st November*, 1907.

Electric Tramways for Benares. *Electrical Engineer, 22nd November*, 1907.

Distribution of Current to Trains on Electric Railways, III. *Railway Engineer, December*, 1907.

Interlocking Circuit-Breakers for Electric Locomotives of the New Haven Type. *Western Electrician, 16th November*, 1907.

Light Freight Handling by Electric Lines. By P. P. Crafts. *Western Electrician, 16th November*, 1907.

Miscellaneous Electrical Subjects.

Distribution and Breadth Coefficients of Alternators. By N. Stahl. *Electrical World, New York, 9th November*, 1907.

Applications of Electric Power for the Widening Work on Blackfriars Bridge. *Electrical Engineering, 21st November*, 1907.

A Directive System of Wireless Telegraphy. By E. Bellini and A. Tosi. *Electrical Engineering, 14th November*, 1907.

Inaugural Address by the Chairman, G. D. Aspinall Parr. *Institution Electrical Engineers, Leeds Local Section, 24th October*, 1907.

Professor Korn's Improved Picture Telegraphy. *Electrical Review, 15th November*, 1907.

Notes on Magnetic Testing of Iron. By W. H. F. Murdoch. *Proceedings Institution Electrical Engineers, 25th November*, 1907.

The Magnetic Testing of Iron. By W. H. F. Murdoch. *Proceedings Institution Electrical Engineeers, 20th August*, 1907.

Constants of Cables and Magnetic Conductors. By E. J. Berg. *Proceedings American Institution Electrical Engineers, October*, 1907.

An Analysis of the Distribution Losses in a Large Central Station System. By L. L. Elden. *Proceedings American Institution Electrical Engineers, November*, 1907.

The Advantages of Turbo-Alternators for Electric Winding. *Colliery Guardian, 29th November*, 1907.

Electrically Operated Pumping Plants. By T. L. Kolkin. *Electrical Review, 6th December*, 1907.

The Belin System of Tele-Photography. *Electrical Review, 6th December*, 1907.

Some recent Improvements in the Wright Mercury Electrolytic Meter. By H. Stafford Hatfield. *Electrician, 6th December*, 1907.

The Commercial Aspect of Electric Power Supply. By W. B. Woodhouse. *Transactions Institution Electrical Engineers, 9th October*, 1907.

Potentiometer Installation. Especially for High Temperature and Thermoelectric Work. By W. P. White. *Physical Review, New York, November*, 1907.

Notes on the Testing of Multi-Range Ammeters and Voltmeters and Low-Reading Voltmeters. By A. E. Moore. *Electrical Engineer, 29th November*, 1907.

Electric Cranes (*continued*). By H. H. Broughton. *Electrician, 22nd November*, 1907.

Wireless Telephony. By J. Erskine Murray. *Times Engineering Supplement, 27th November*, 1907.

Electrical Equipment of a Cement Works. *Electrical Engineering, 28th November*, 1907.

The Relation between Polarization and the Corrosion of Iron Pipes by Stray Currents. *Stevens' Institute Indicator, October*, 1907.

Marine Engineering and Naval Architecture.

The First French Turbine Steamer. By Jules Peltier. *International Marine Engineering, December*, 1907.

The Hamburg-American Steamer *Kronprinzessin Cecilie. International Marine Engineering, December*, 1907.

Streets and Pavements.

Water Supply.

The Rand Water Board Plant and Works, II., III. *Engineer, 15th* and *22nd November*, 1907.

Sand Filtration of Water Supplies. By A. Williamson, II. *Engineering, 22nd November*, 1907.

Some Notes on Oriental Waterworks. By G. A. Johnson. *Engineering News, 7th November*, 1907.

The Filtration of the Croton Water Supply of New York. *Engineering Record, 23rd November*, 1907.

Sewage.

A Large Reinforced Concrete Sewer in the Borough of Queens, New York City. *Engineering Record, 30th November*, 1907.

Municipal Sewage Disposal. An Investigation. By J. T. Fetherston. *Proceedings American Society Civil Engineers, November*, 1907.

A Short Method of Recomputing Sewer Discharges for a changed value of "n" in Kutter's Formula. By G. S. Coleman. *Engineering News, 21st November*, 1907.

Engineering Economics and Works Management.

The Cost of Depreciation. By A. S. Atkinson, *Engineer, Chicago, 2nd December*, 1907.

Miscellaneous.

Air Washing and Humidifying and Some of its Applications to Industrial Purposes. By W. A. Rowe. *Engineer, Chicago, 2nd December*, 1907.

Rifled Artillery. By A. G. Greenhill. *Engineer, 22nd, 29th November*, and *6th December*, 1907.

Some Comparisons between French and English Artillery. By M. Gustave Canet. Inaugural address to Junior Institution of Engineers. 18th November, 1907. *Practical Engineer, 22nd November*, 1907.

The Franco-British Exhibition (*continued*). *Engineer, 6th December*, 1907.

Modern French Field Guns. *Engineering, 6th December*, 1907.

Deflocculated Graphite. By E. G. Acheson. *Journal Franklin Institute, November*, 1907.

Experiments on Wind Pressure. By T. E. Stanton. *Transactions Institution Civil Engineers, 3rd December*, 1907.

The Manufacture and Use of Copper-Clad Steel. *Engineering News, 14th November*, 1907.

Mine Surveying. By C. E. Morrison. *School of Mines Quarterly, November*, 1907.

Malleable Cast Iron. By Bradley Stoughton. *School of Mines Quarterly, November*, 1907.

Acetylene Lighting and Storage. By R. E. Bruckner. *Stevens' Institute Indicator, October*, 1907.

The Production of Steel Ingots for Large Crank Shafts. *Iron and Coal Trades Review, 15th November*, 1907.

Faults of Iron Castings II. *Machinery, November*, 1907.

Foundry Cupola and Iron Mixtures. By W. J. Keep. *Proceedings American Society Mechanical Engineers, November*, 1907.

Specifications for Iron and Coke and Method of Testing Foundry Output. By R. Moldinke. *Proceedings American Society Mechanical Engineers, November*, 1907.

A Volumetric Study of Cast Iron. By H. M. Lane. *Proceedings American Society Mechanical Engineers, November*, 1907.

MANUFACTURERS' NOTES.

The Direct Photo Engraving Co., 38, Farringdon Street, E.C. This business—one of the oldest in the trade—has been converted into a limited liability company, and we are notified that Mr. John Swain, son of the late John Swain, the well-known photo-engraver, has joined the Board with Mr. F. E. S. Perry. **Samuel Denison & Son,** Leeds. In connection with the extensions now proceeding at this firm's Knostrop Sewage Works, the Leeds Corporation has placed an order with them for a weighbridge to be constructed for a diversity of traffic including ordinary railway wagons; tramway trucks to a gauge of 24 ins.; road traction engines ; motor wagons and ordinary carts and drays. The platform will have four grooves, each with inserted steel rails. There will be no obstructions of the surface of the weigh-plate or platform to interfere with foot passengers or road vehicles crossing it in any direction. The firm's single type steelyard has been selected, and it is to be graduated by dividing engine with their non-wearing notch, which obviates the use of pawl protection bars or other devices for preventing undue wear of the tongue or pawl of the sliding poise weight. **Messrs. Heenan & Froude, Ltd.,** have opened offices at 56, Victoria Street, S.W., under the control of Mr. Robert H. Hammersley Heenan, M.Inst.C.E., M.I.E.E., who, having recently retired from the position of General Manager and Engineer-inChief, Table Bay Harbour and Docks, has now joined the Board. Messrs. J. B. Corrie & Company, of Queen Anne's Mansions, will continue as heretofore to act as the firm's agents in London for South America and other Foreign Countries. **Messrs. Marples, Leach & Co.,** of 6, Victoria Avenue, Bishopsgate Street Without, E.C., electrical engineers and suppliers, have forwarded us a neat little memento in the form of a 6 in. slide rule. They inform us that they would be pleased to send one of these on to any reader who will drop a postcard to them. This is an attractive little novelty, and cannot fail to be appreciated by our readers.

IMPORTANT NOTICE.

Testing a Centrifugal Fan.—Readers of this interesting series of articles by Mr. C. L. Browne would notice, upon reaching the paragraph commencing "This efficiency of the fan alone" in the right hand column of page 376 of the December issue, a break occurs in the continuity of the subject under treatment. This is due to the fact that, through an inexplicable oversight, several paragraphs were "dropped" at the point above mentioned. Readers are notified, however, that the dropped matter will be printed with the next instalment of the series.

The Index and Title for Volume XVII. will be issued with the February Number.

WORKSHOP PRACTICE PRIZE COMPETITION.

The award of £10 for the best article on Live Steam Feed Heating has been made to MR. A. H. GIBSON, M.Sc., A.M.Inst.C.E., whose contribution appears on another page.

Our Fourth Prize Competition relates to Workshop Practice, and is limited to Works Managers, Foremen, and those under their charge, to provide an opportunity of bringing their practical ideas and experiences into print.

Four prizes are offered—one of £4 and three of £1—for the best short article describing and illustrating any emergency device or any job which has taxed the ingenuity of the machinist, pattern maker, fitter or foundry operator.

The award will be announced in the February number.

INSTRUCTIONS AND CONDITIONS.

Articles must be written on one side of the paper only, and be signed by the competitor.

Drawings and sketches must be on separate sheets of paper.

A short biographical sketch of the competitor's technical experience should accompany the article.

The right is reserved of publishing the prize article, and also any of the others sent in; but in the case of the latter, payment will be made for the same at our usual scale rates.

The Editor's decision in all matters connected with the competitions shall be final, and binding on all the competitors.

All articles should be addressed to the Editor of THE ENGINEERING REVIEW, 104, High Holborn, London, W.C., and marked on the outside, "Competition," and the same must be received not later than January 15th.